Pierce's disease epidemiology and management in the Coast Range

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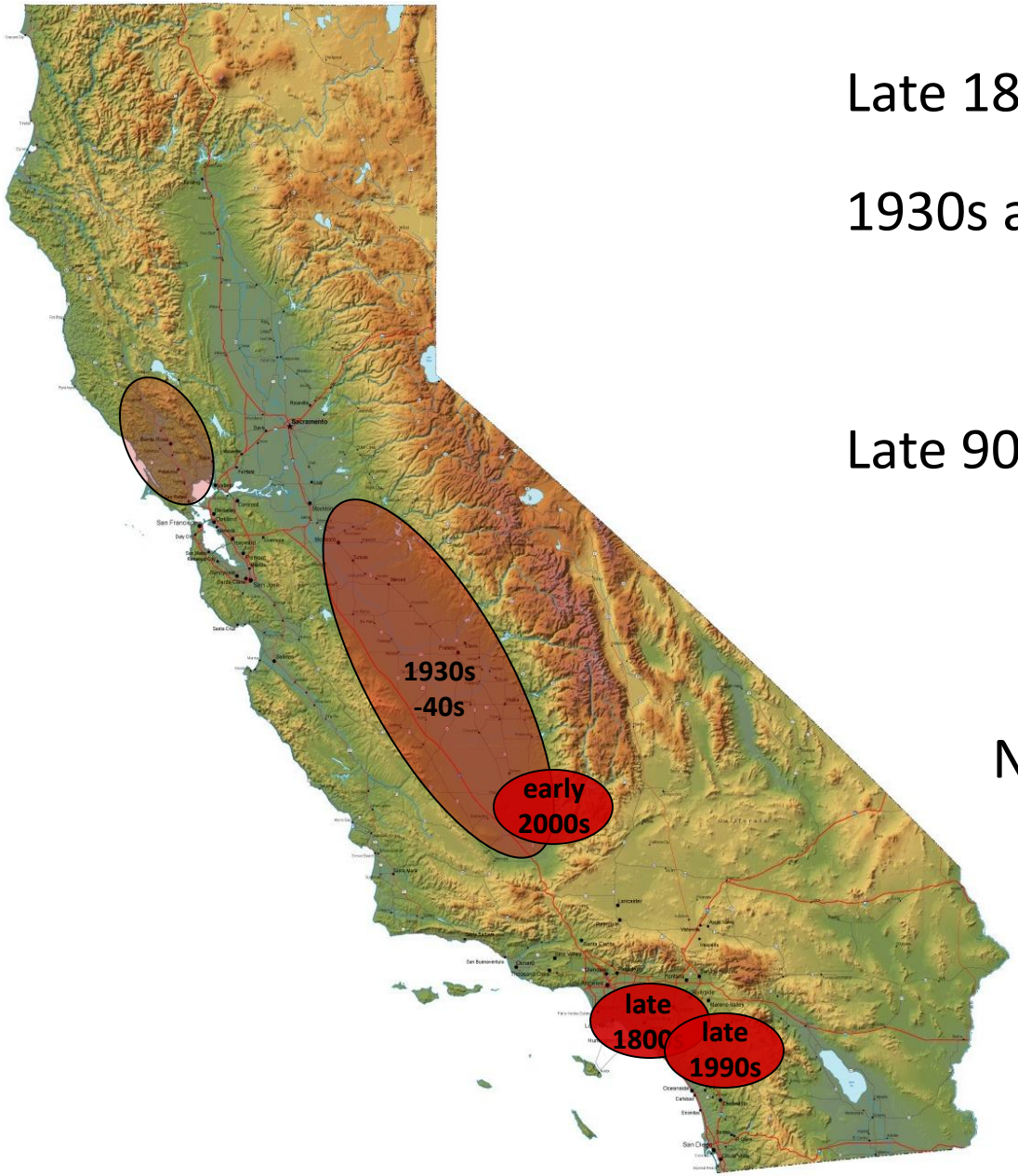
Severe PD outbreaks are unusual



Late 1800s: Anaheim vine disease

1930s and 40s: Central Valley

-alfalfa

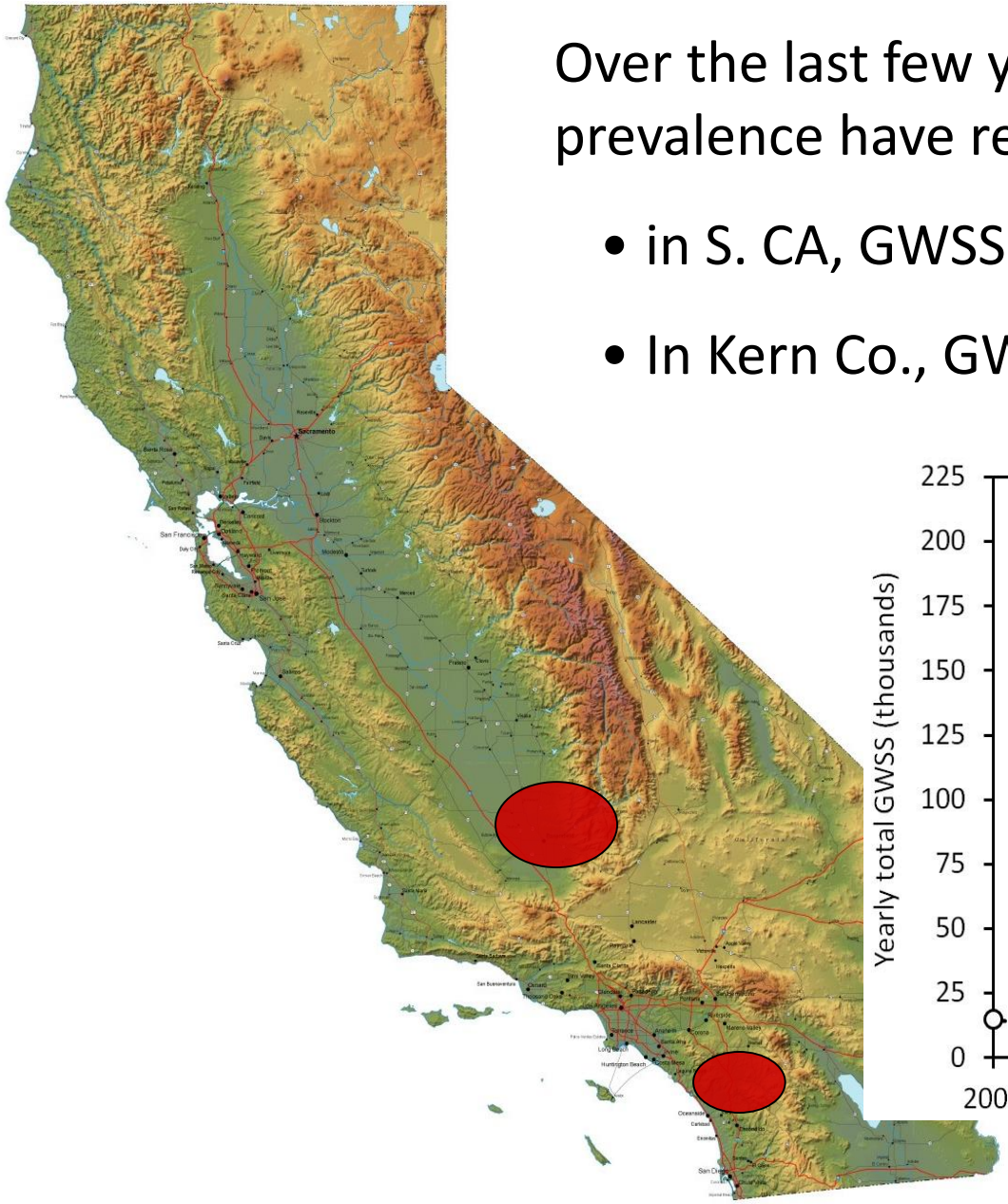
Late 90s - early 2000s: Temecula Valley and Kern County

-invasive GWSS

North coast: usually moderate, episodic

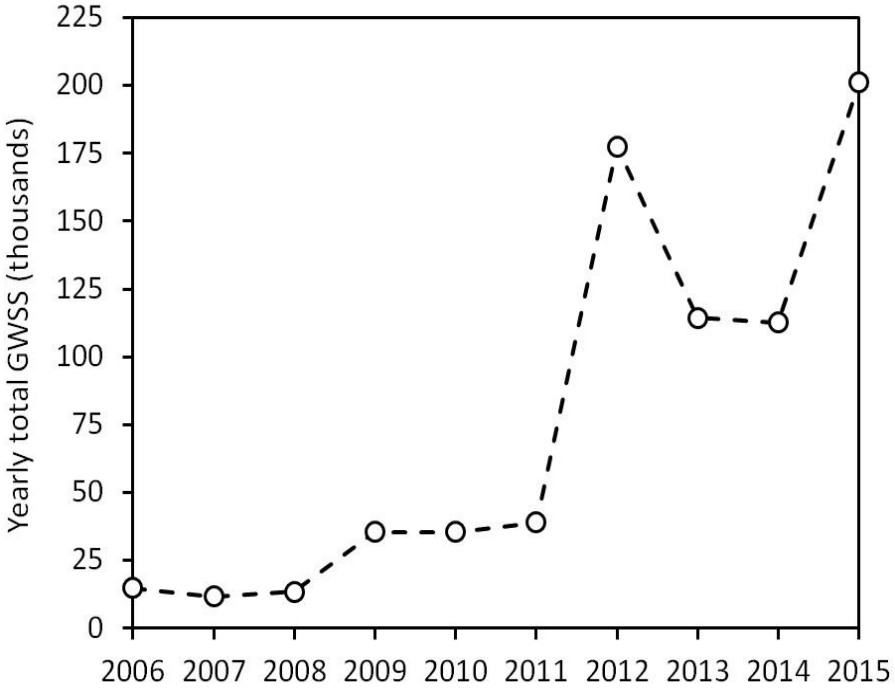
-native BGSS

Severe PD outbreaks are unusual

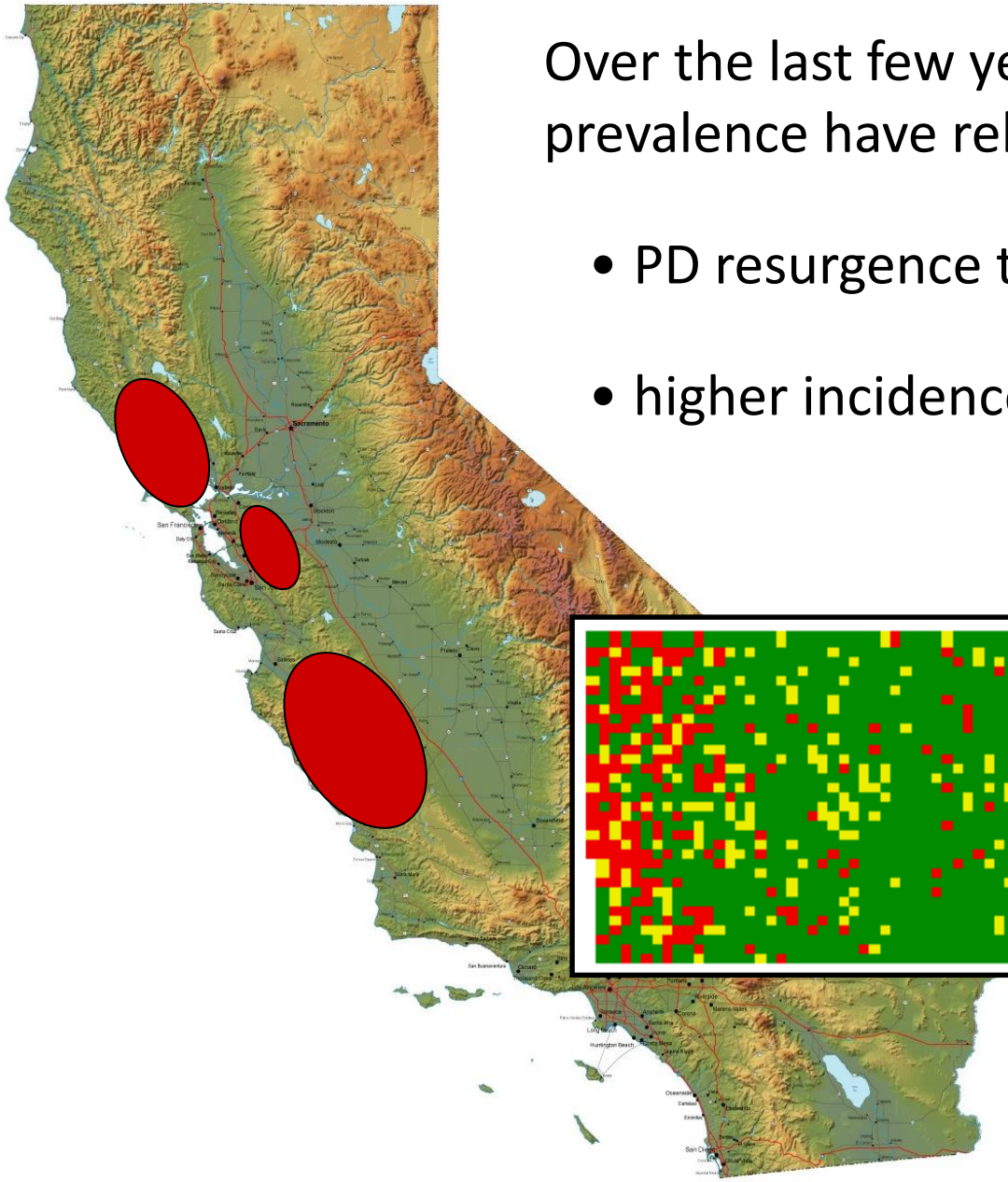


Over the last few years vector populations or PD prevalence have rebounded

- in S. CA, GWSS catch is highest since 2003
- In Kern Co., GWSS up nearly 10-fold

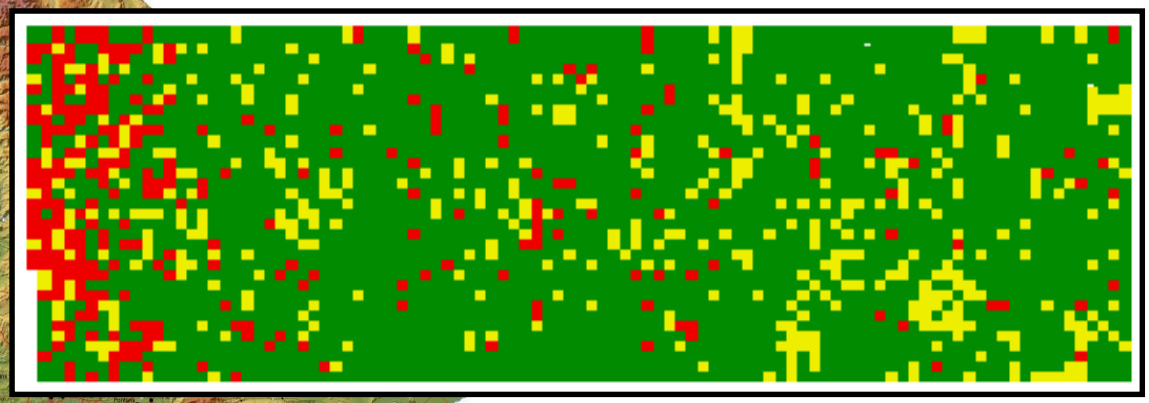


Severe PD outbreaks are unusual



Over the last few years vector populations or PD prevalence have rebounded

- PD resurgence throughout the coast range?
- higher incidence and different patterns



1. Background on *Xylella fastidiosa* transmission and vectors

2. What's driving the current PD epidemic

    - predicting PD, vector incidence?

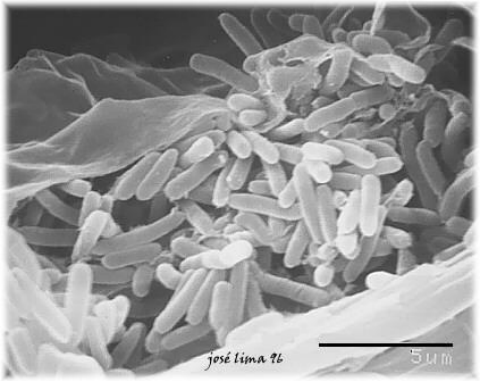
3. PD management in the Coast Range

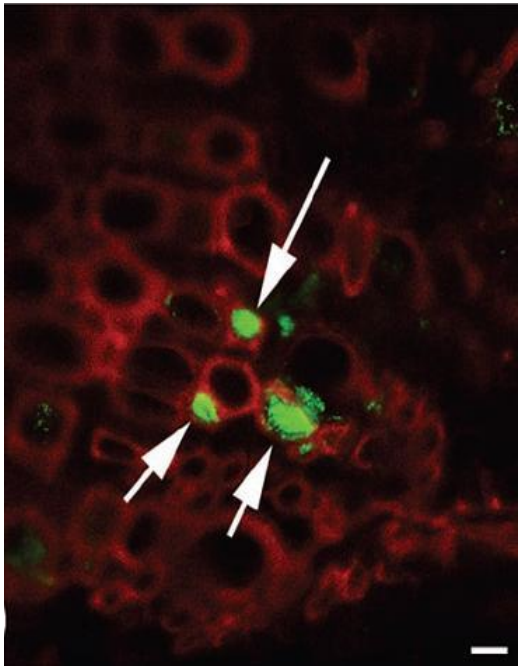
Xylella fastidiosa

Xylem-limited bacterium

Infects native, ornamental, & weedy plants

Threat to several crops
(e.g., grapes, almond, citrus, alfalfa)





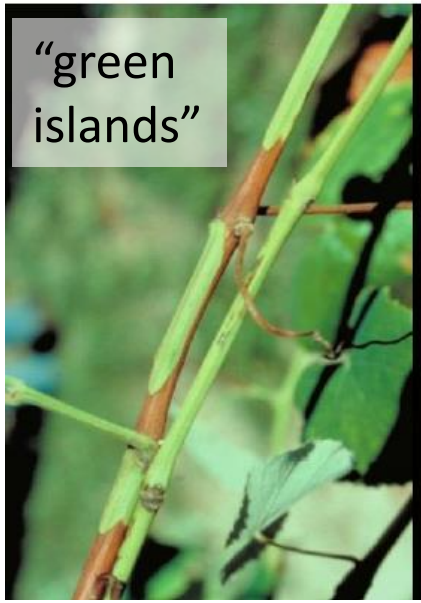
Xylella diseases

Plugs xylem vessels, restricts water flow

Leaf scorch or stunting symptoms vary among hosts (Pierce's disease in grapes, Alfalfa dwarf)

No cure

Pierce's disease



Non-*Xylella* diseases of grapevines

Grape measles (Esca)

Eutypa dieback

Grapevine leafroll disease


almond
pecan
oleander
olive
alfalfa dwarf
coffee
plum
citrus variegated
chlorosis
sweet gum

Olive quick decline syndrome

Xylella fastidiosa transmission

Transmitted by xylem sap-feeding insects

- some leafhoppers, spittlebugs

No transovarial transmission

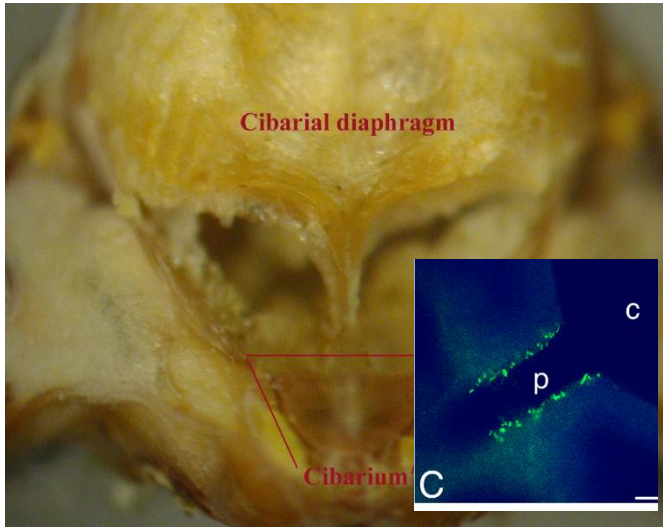
No latent period

Nymphs & adults can transmit

- no transmission after molting
- persistent in adults

Vector species differ in efficiency

- depends on *Xylella* strain, host plant



Blue-green sharpshooter (*Graphocephala atropunctata*)

Dominant vector of *Xylella* in the coast range

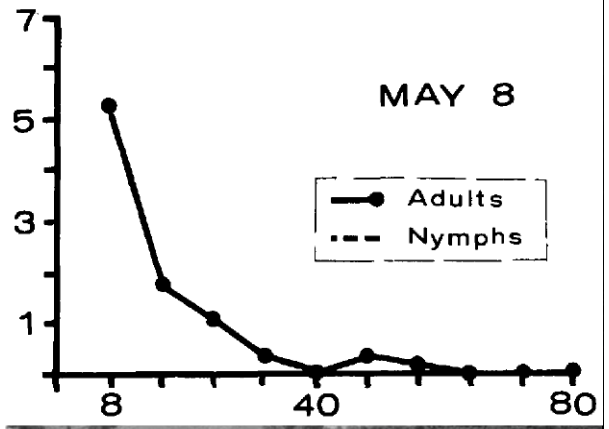
Strong association with riparian habitats

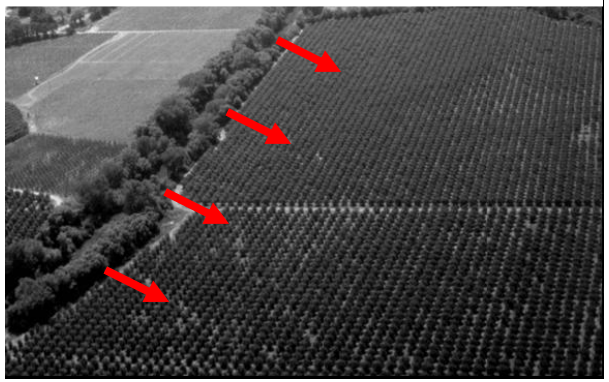
- wild grape, blackberry, vinca….

Active in vineyards in Spring, when days become warmer

- multiple days > 65˚F
- peak ~May, smaller peak mid-Summer

Does not travel far into vineyards; PD along margins





Other native vectors

Smoke tree sharpshooter (*Homalodisca liturata*)

- present in interior, S. CA
- much less abundant than GWSS
- modest transmission efficiency

Willow sharpshooter (*Neokolla confluens*)

- common in riparian habitats
- rare in vineyards
- medium transmission efficiency

Other native vectors

Red-headed sharpshooter (*Xyphon fulgida*)

- prefers grasses (esp. Bermuda grass)
- locally abundant where weedy grasses occur
- moderate efficiency

Green sharpshooter (*Draeculacephala minerva*)

- prefers grasses, sedges
- common in irrigated pastures and ditches
- important vector for alfalfa & almond, less efficient to grapevines

Other native vectors

Meadow spittlebug (*Philaenus spumarius*)



- cosmopolitan xylem-sap feeder
- appearance varies (multiple morphs)
- nymph spittle masses easy to see in spring
- locally abundant on some forbs and grasses, including weeds
- low transmission efficiency?

Glassy-winged sharpshooter (*Homalodisca vitripennis*)

Native to SE USA

First documented in CA in 1989

Spread throughout S. CA, S. Central Valley, select areas further North

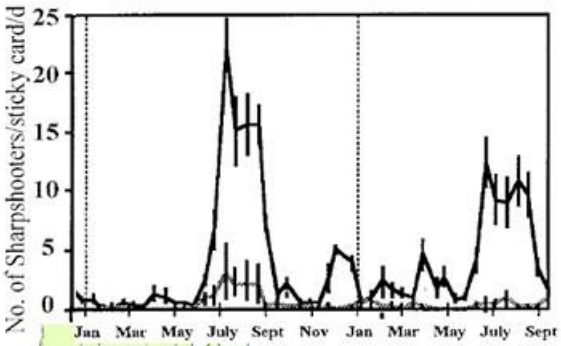
Extremely broad host range

-350+ plant taxa on CDFA list

https://www.cdfa.ca.gov/pdcp/Documents/HostListCommon.pdf

Relatively inefficient vector of *Xylella*

Glassy-winged sharpshooter (*Homalodisca vitripennis*)



Relatively inefficient at transmitting *Xylella*, but…

- more active throughout the year
- willing to feed on woody plant material
- able to fly further than other vectors
- multiple generations a year
- capable of very high population growth rates

What explains the current PD epidemic?

Rodrigo Almeida

Dylan Beal

Monica Cooper

Matt Daugherty

Sandy Purcell

Rhonda Smith

Lucia Varela

Pierce's Disease Control Program

What explains the current PD epidemic?

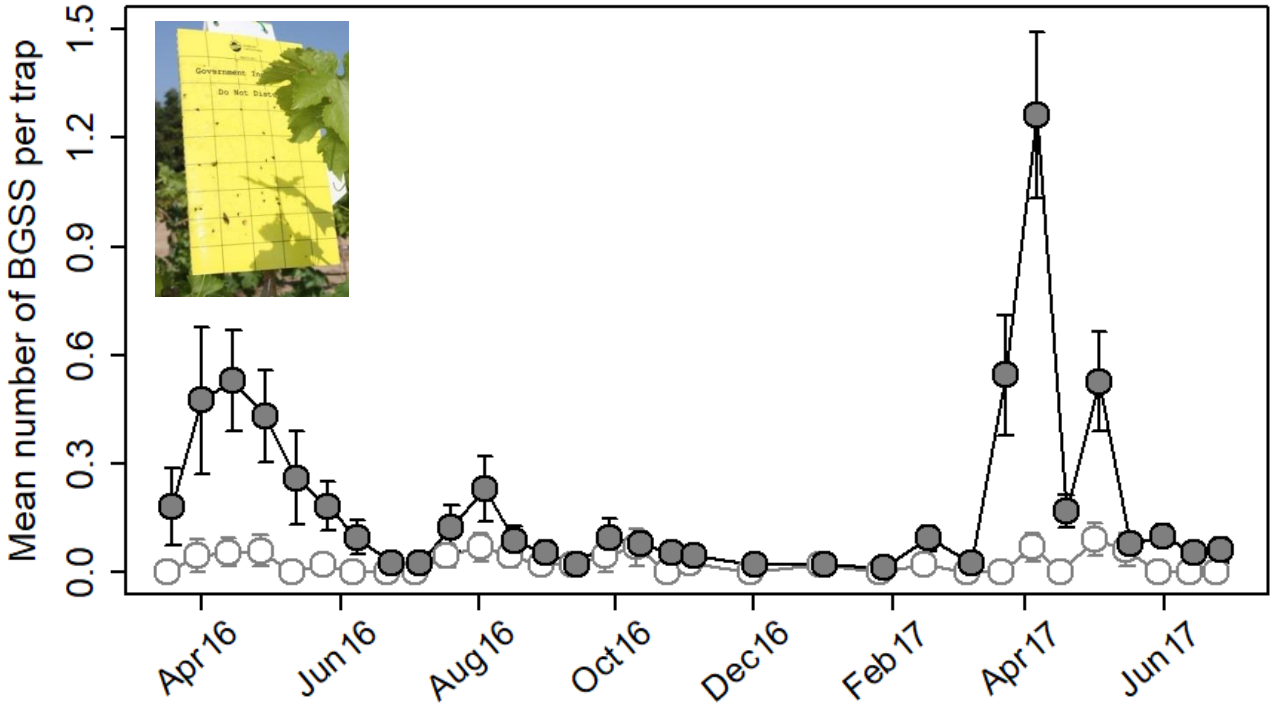
Higher PD prevalence than typical and different patterns

Detailed monitoring at 32 sites in Napa and Sonoma

1. Patterns of vector abundance
2. Patterns of PD distribution
3. Novel *Xylella fastidiosa* genotype?
4. New or formerly underappreciated vector?
5. Climatic conditions?

Vector abundance – BGSS phenology

Relatively low trap catch, but lots of variability among sites

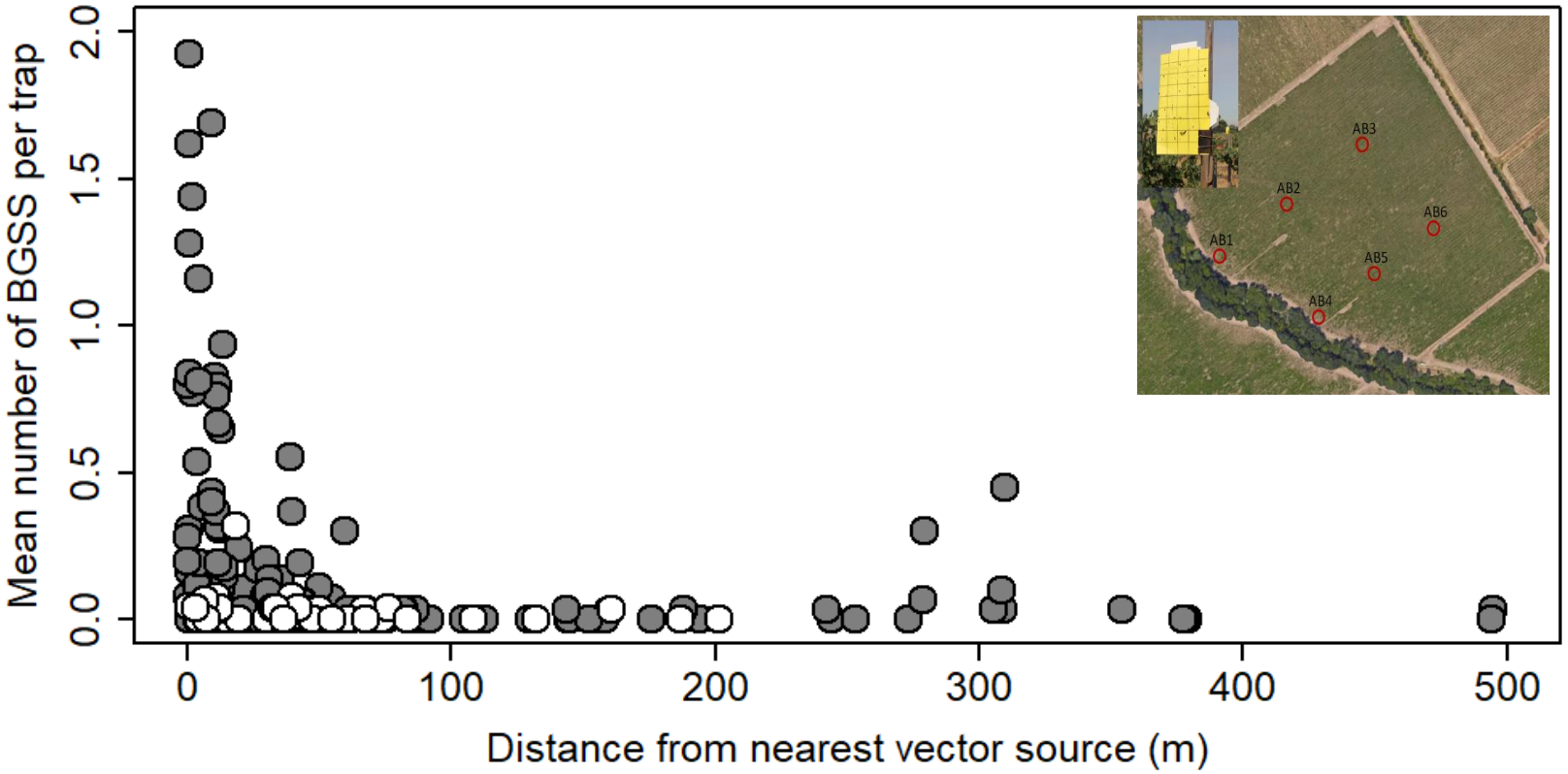


BGSS far more common at “riparian” vs “non-riparian” sites

Late-Spring and late-Summer peaks

Vector abundance – BGSS distribution

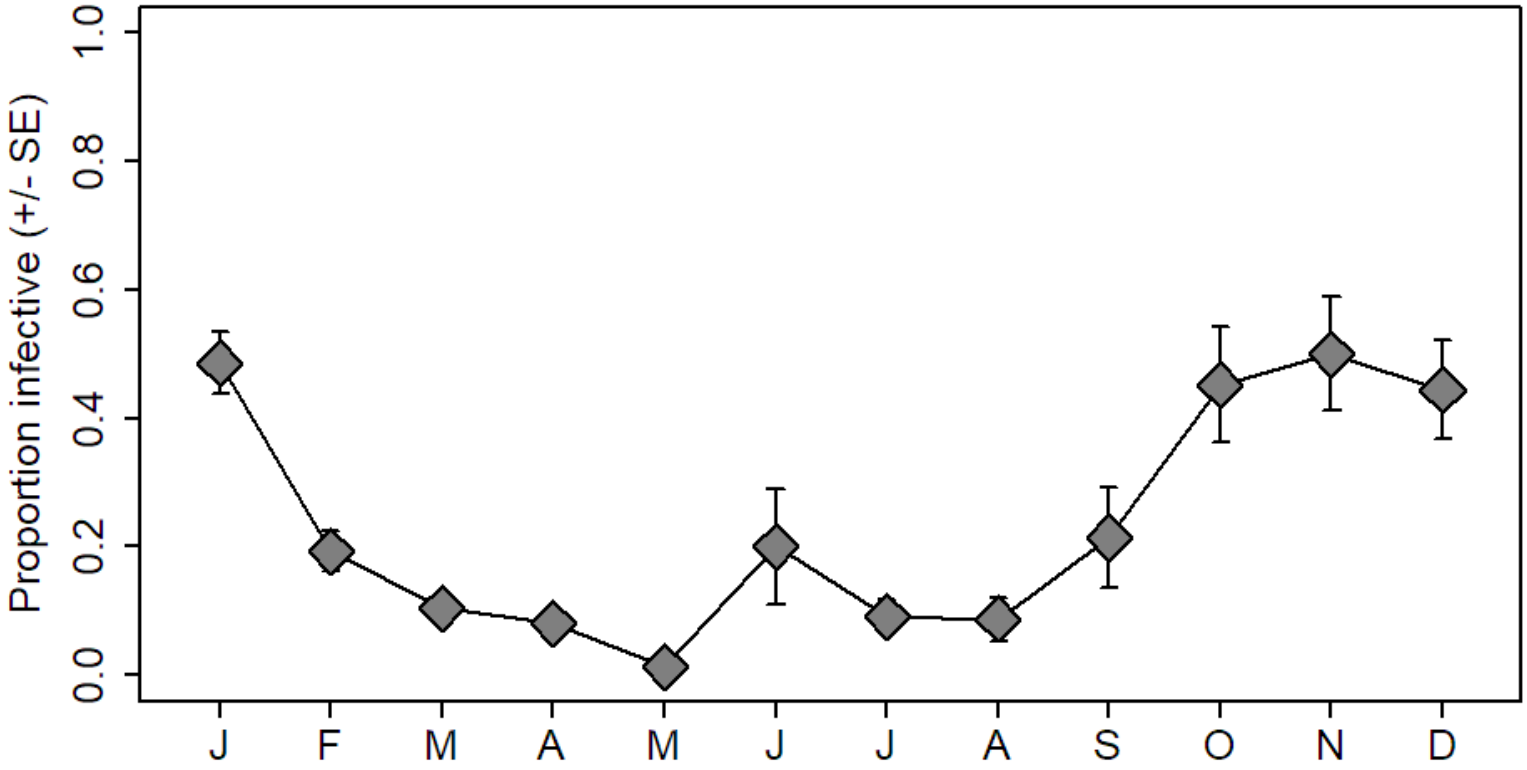
Vast majority of BGSS caught at riparian interface



~10% of traps had any BGSS beyond 50m of vineyard edge

Vector abundance – BGSS distribution

Overall, ~15% infective but seasonally variable



Low infectivity Fall through Winter, low through Summer

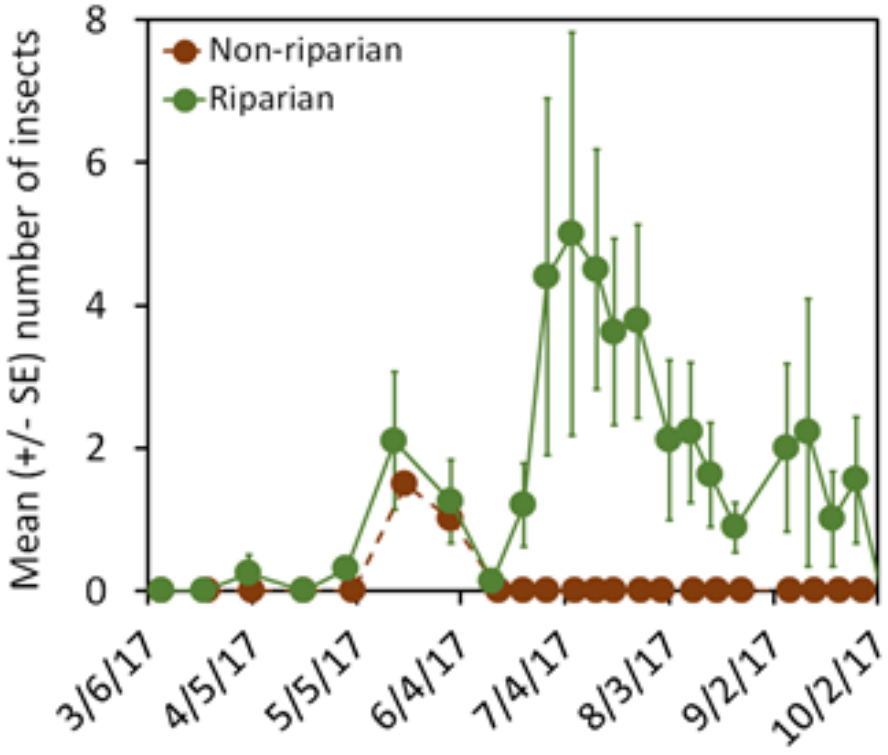
Vector abundance – Sweep net sampling

Vector community composition varied by county and site

- Sonoma: 44% BGSS, 31% RHSS, 18% SB, 3% *Pagaronia*
- Napa: 0% BGSS, 0% RHSS, 36% SB, 63% *Pagaronia*

All vectors are rare at non-riparian sites

Certain vectors active in vineyards at riparian sites for much of the year



Observed PD patterns

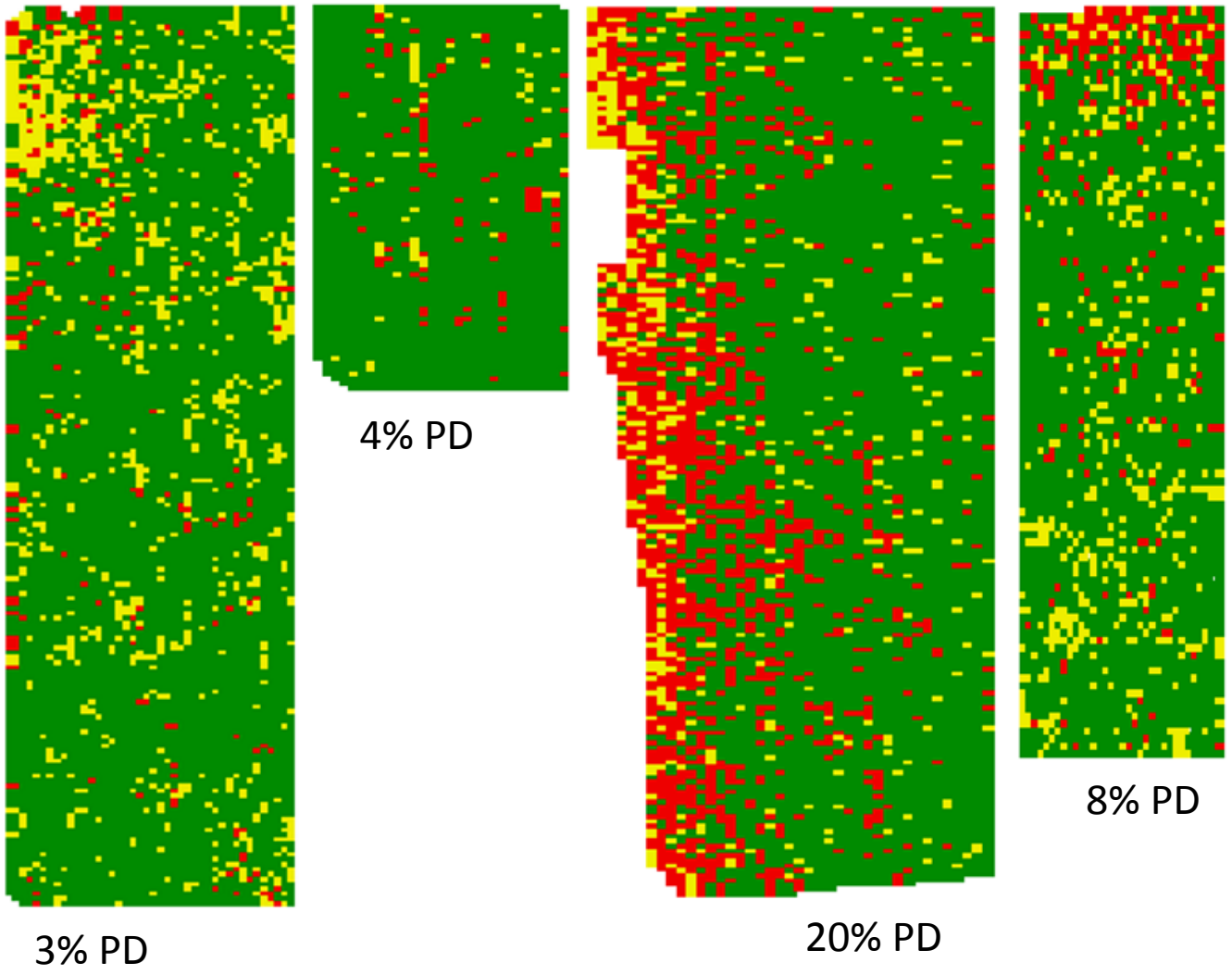
Pierce's disease mapping in Fall 2016, 2017, and 2018

Spatial analysis of disease patterns

- evidence of PD clustering?
- location of PD clusters?
- gradient in disease from potential "source" habitat ("anisotropy")?

Observed PD patterns

green=healthy, red = PD, yellow = dead, missing, or replant

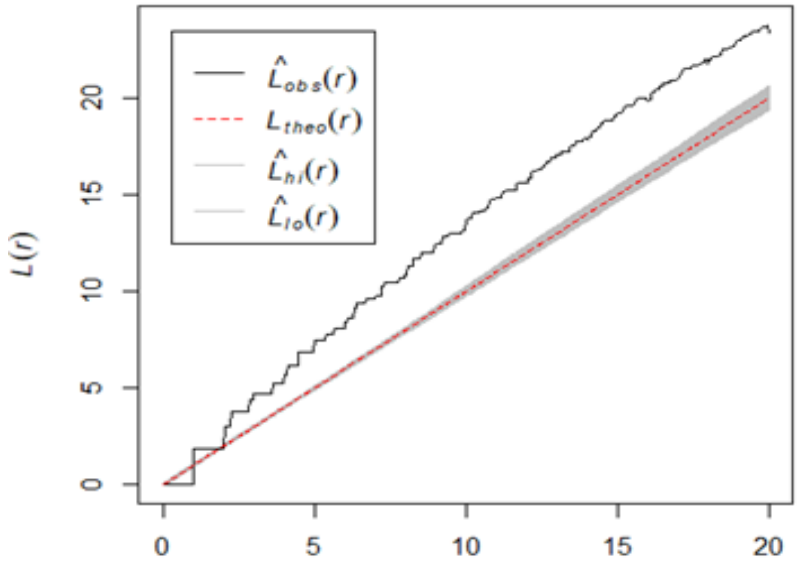


Observed PD patterns

<u>Riparian sites</u>

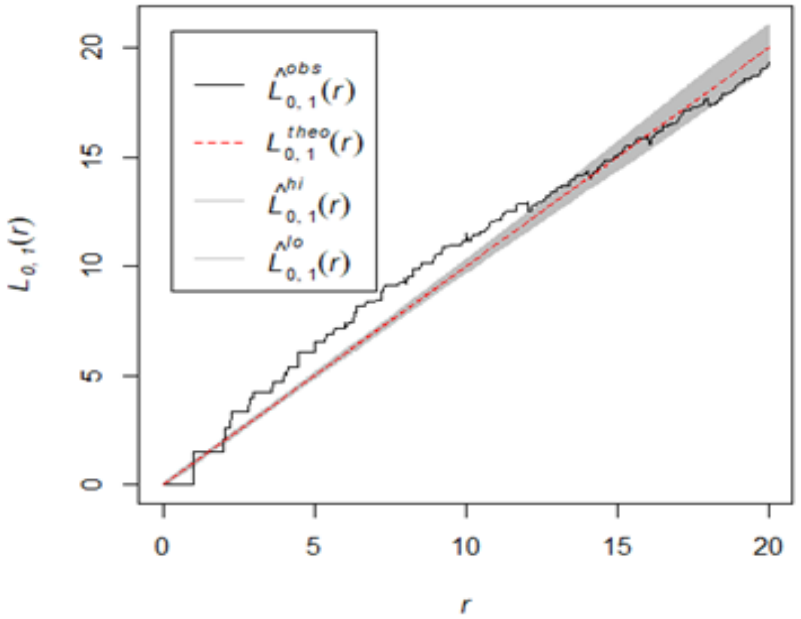
Significant clustering of PD cases

- indicator of vector activity?



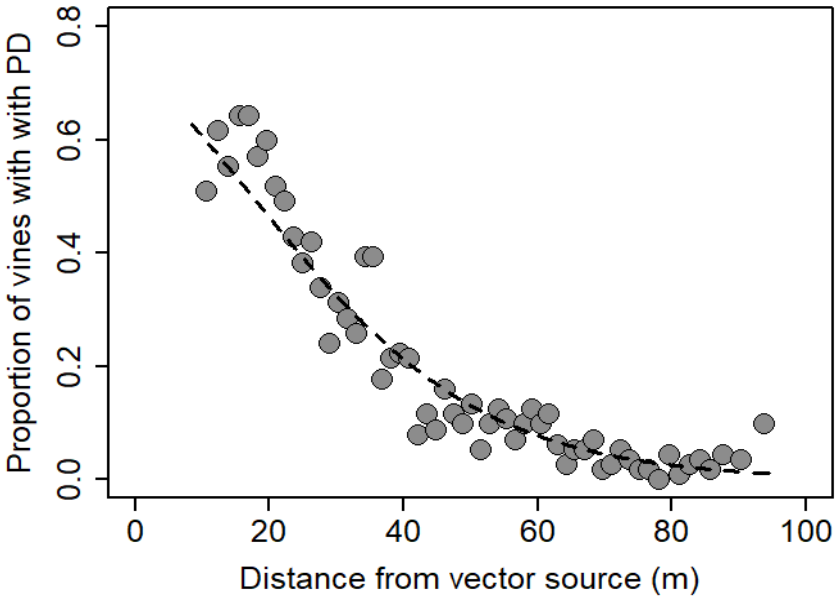
Co-clustering of PD and dead, missing, or replant vines

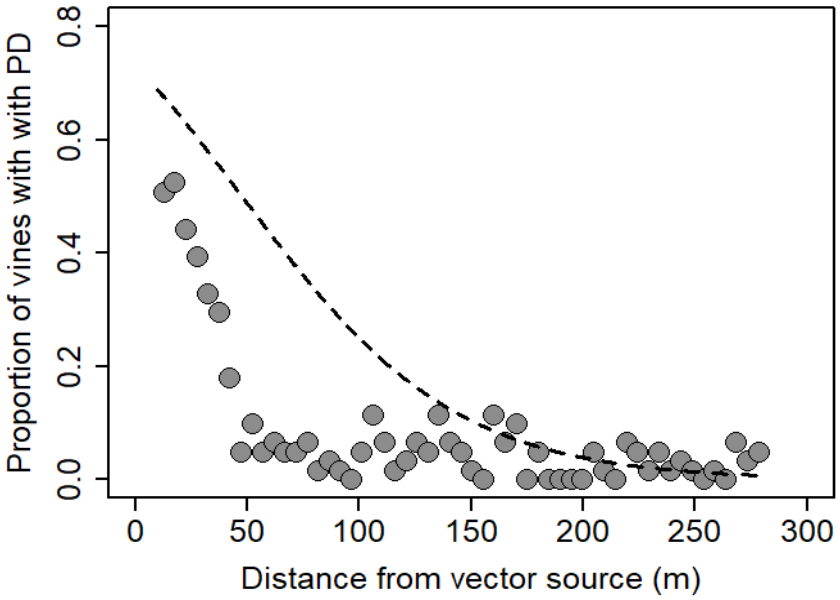
- current estimate of PD is conservative?



Observed PD patterns

Riparian sites





Significant gradients in disease prevalence

- distance from vector source
- significant risk of PD more than 80 m from source

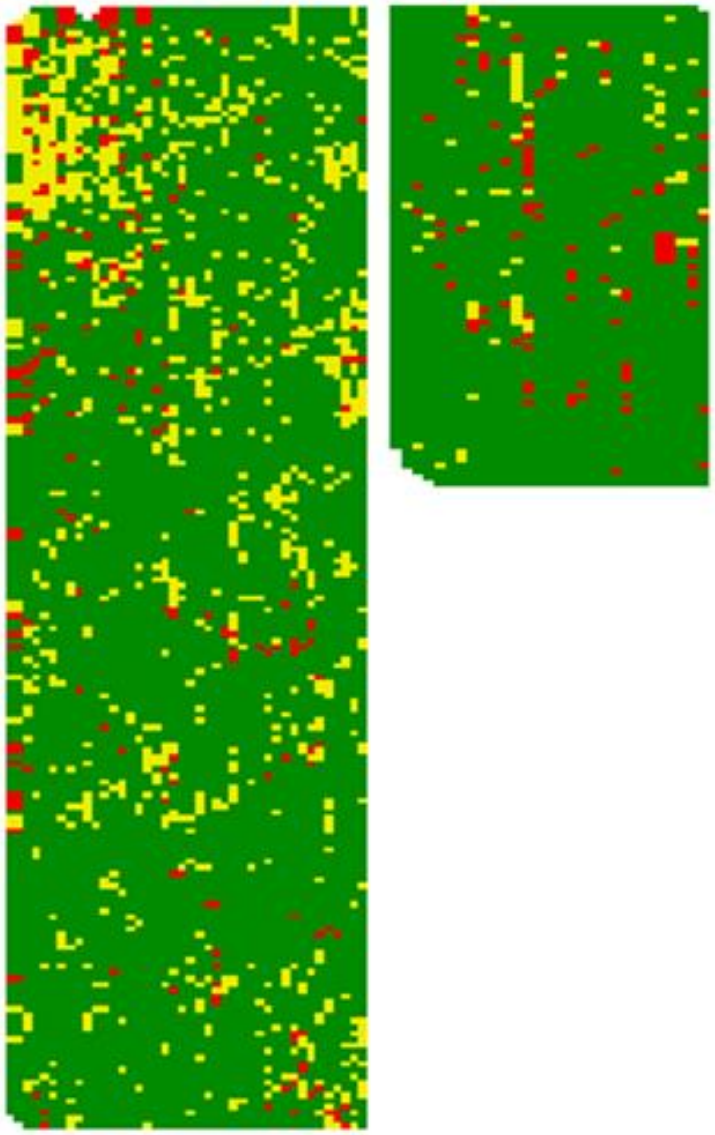
Observed PD patterns

<u>Non-riparian sites</u>

No significant anisotropy in PD distribution

Significant PD clustering

- some clusters distant from edge of blocks
- indicative of activity by other vectors?



Observed PD patterns

NEXT STEP: estimate year-to-year change in PD prevalence and which factors are driving it

$$PD_t \sim BGSS_t + \text{Other vectors}_t + \%PD_{t-1}$$

1. How low does # of BGSS have to be to curb PD incidence?

2. Are other vectors worth managing?

3. Does prior disease contribute to new disease

   - roguing might be more important than we think

Why more PD – a new strain of the pathogen?

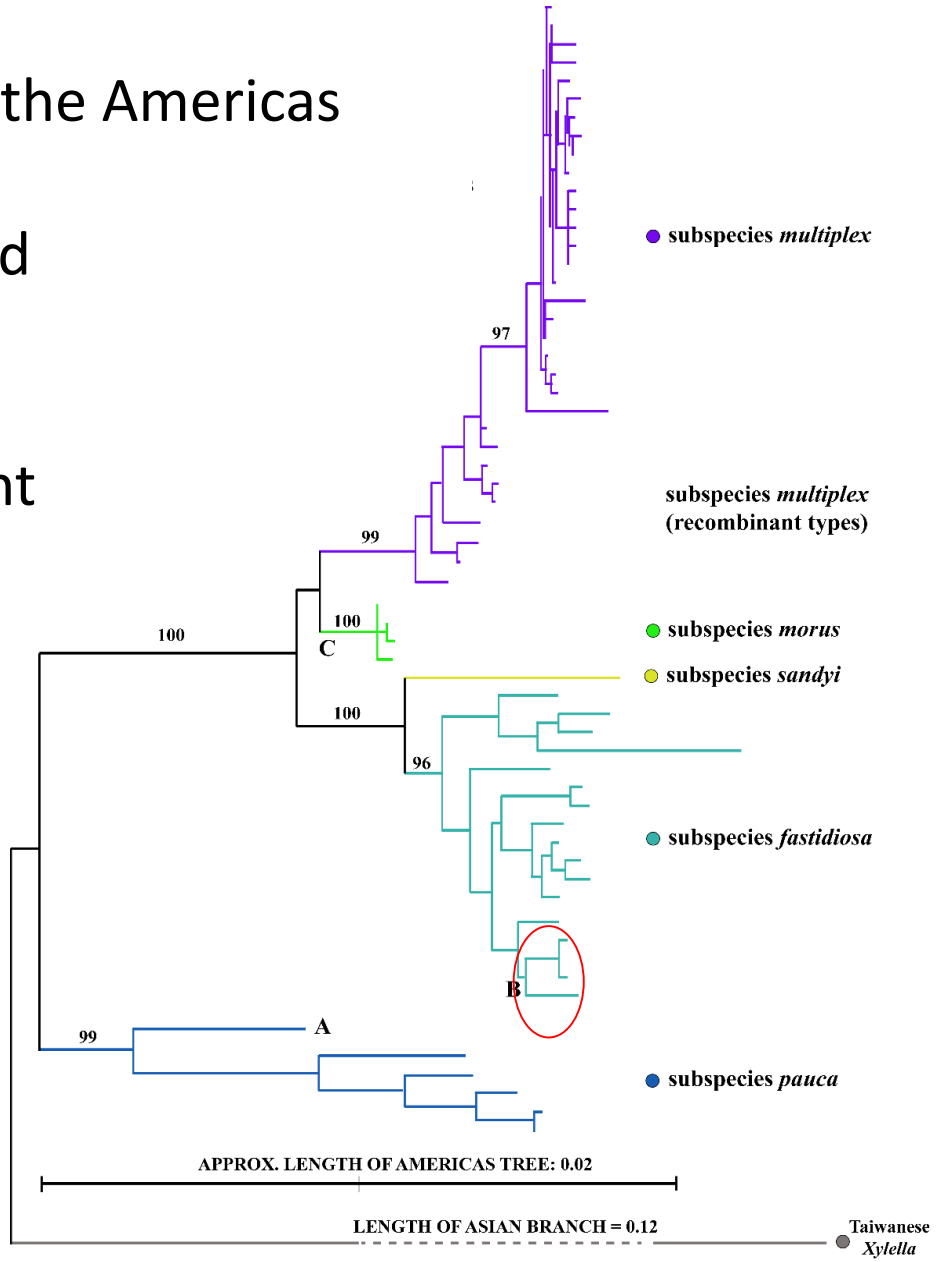
Multiple strains of *Xylella* exist in the Americas

Strains differ in their virulence and transmissibility

Is a novel strain driving the current epidemic?

Population genomics being used to compare

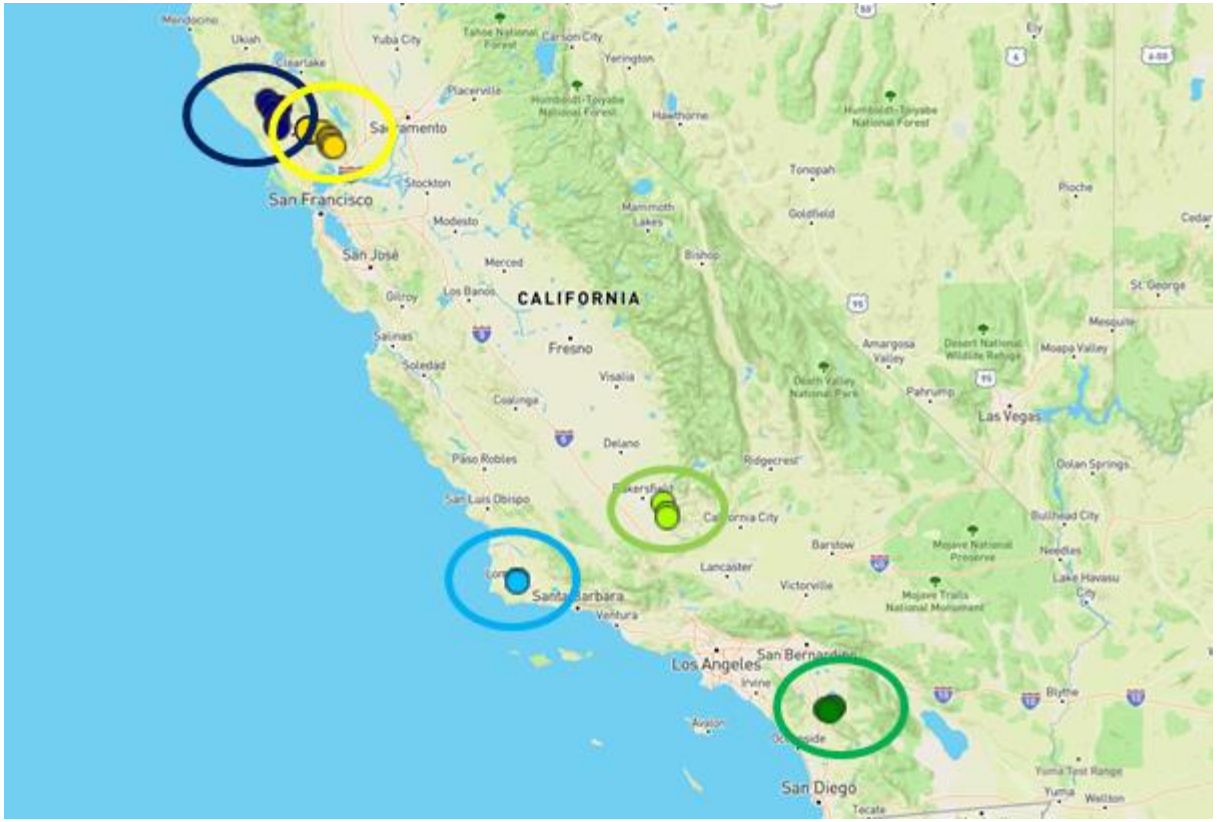
- relatedness of isolates throughout CA
- current vs. historical isolates



Why more PD – a new strain of the pathogen?

Sequenced 122 isolates collected throughout California

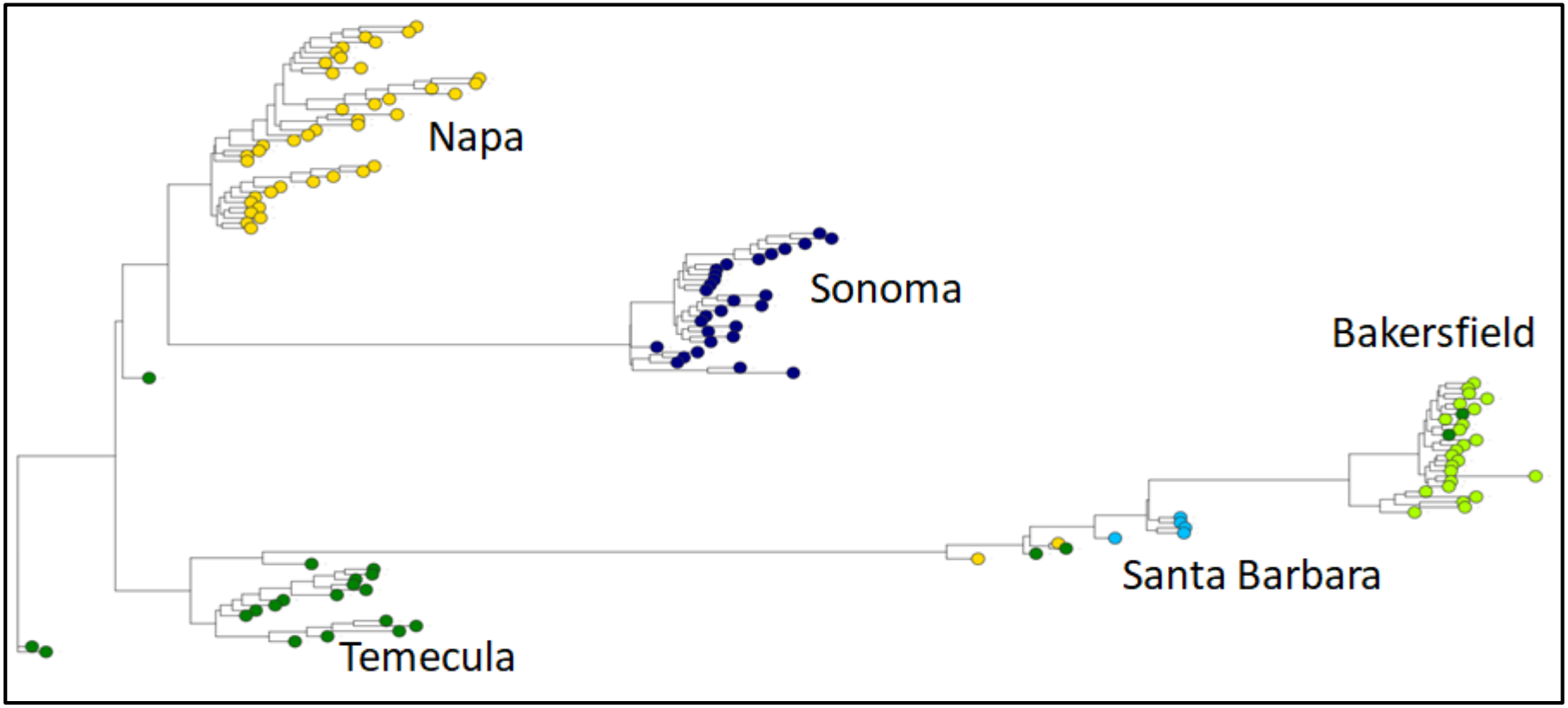
Temecula (23), Santa Barbara (5), Bakersfield (25), Napa (41), Sonoma (28)



Why more PD – a new strain of the pathogen?

Locations are genetically structured

- preliminary evidence that climate reinforces structure



No evidence of novel, more virulent genotype in N. CA

Why more PD – a new(ly appreciated) vector?

Spittlebugs (*Philaenus spumarius)* are known vectors of *Xylella*

Can be locally abundant in some vineyards on a wide range of forbs/weeds

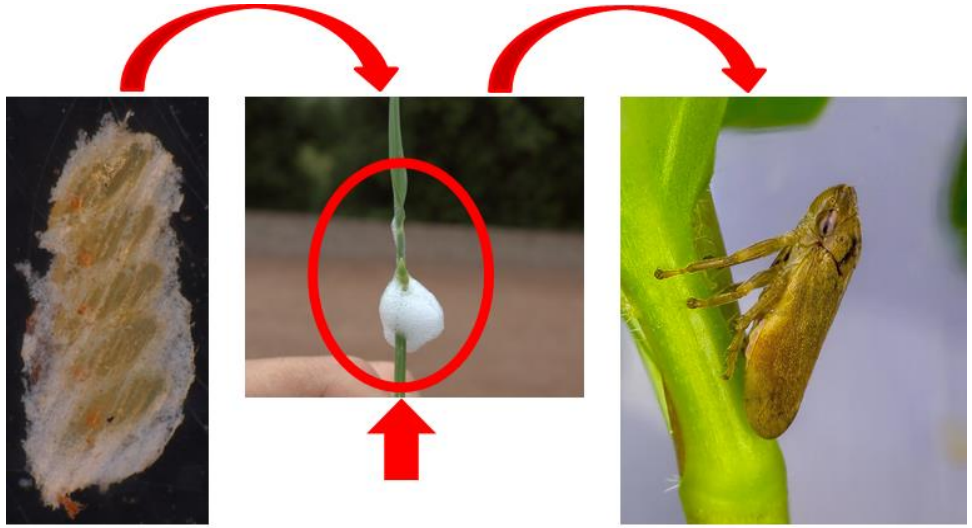


Photo credit: Daniele Cornara

Are spittlebugs now an important vector?

- less efficient that BGSS, but much of its biology isn't known

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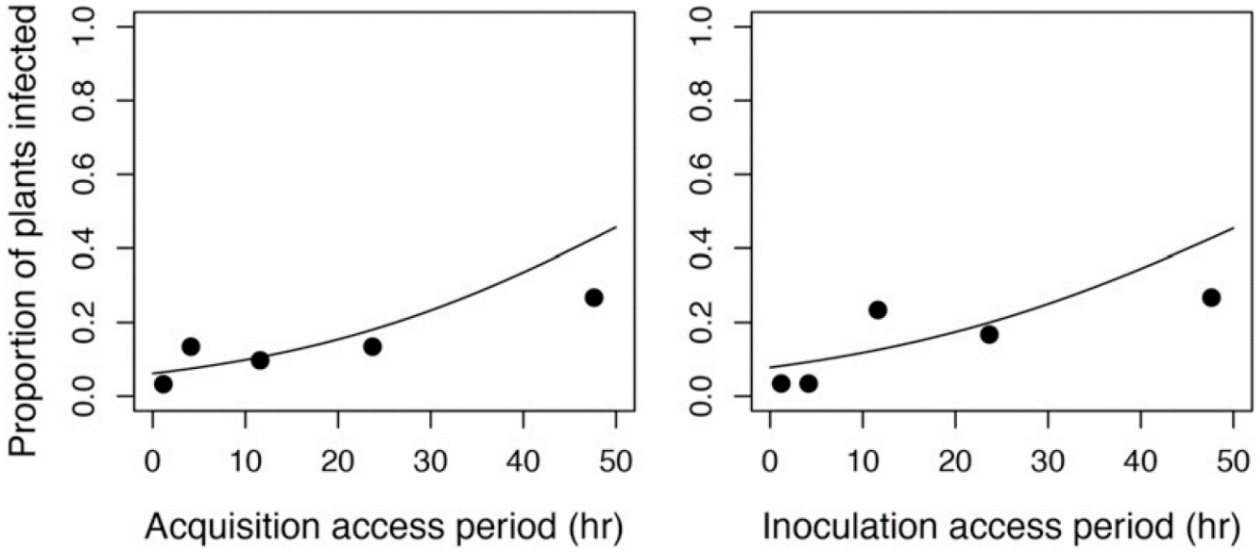

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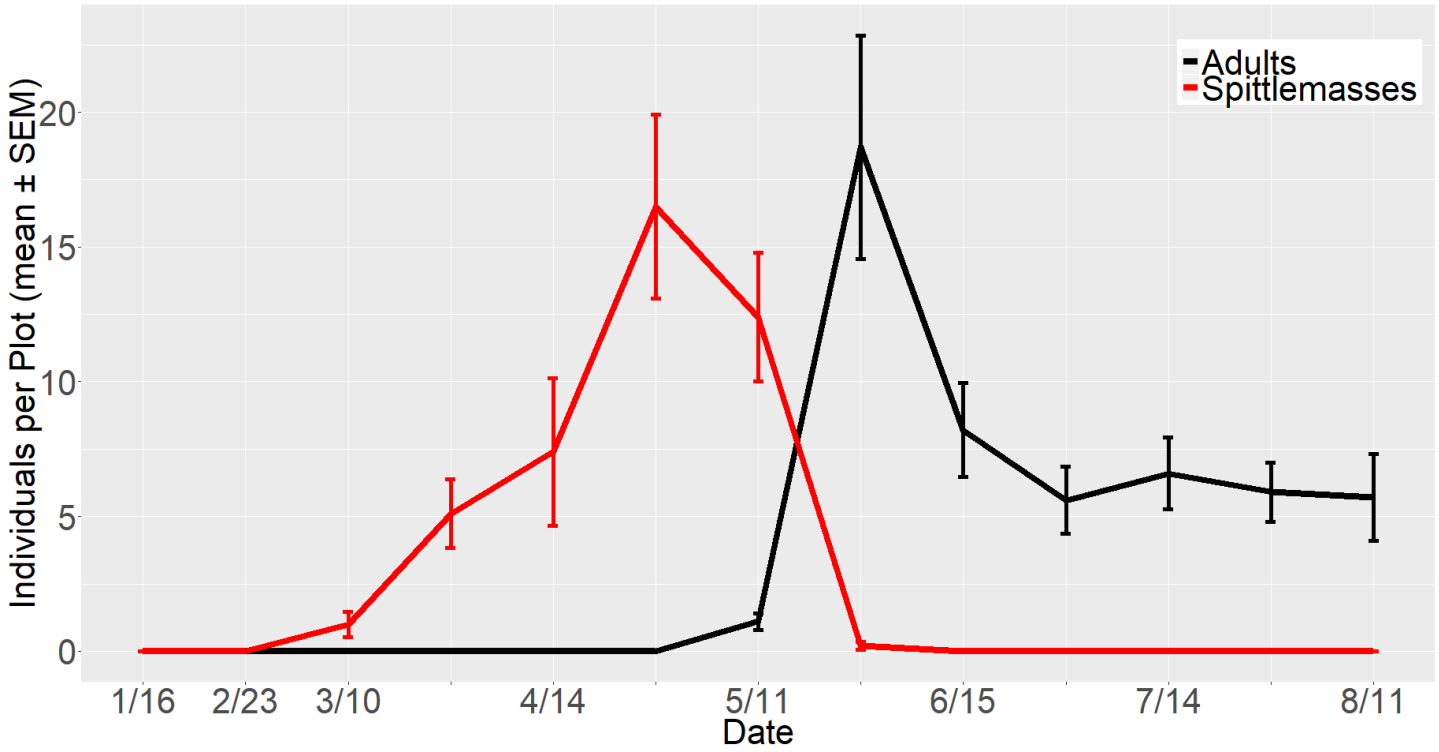
Why more PD – a new(ly appreciated) vector?

Surveys for seasonal phenology, host plant use to better understand its biology



- nymphs (spittle masses) peak mid-Spring
- adults most abundant late-Spring to early Summer

Why more PD – a new(ly appreciated) vector?

Surveys for seasonal phenology, host plant use to better understand its biology

Bristly oxtongue

Cutleaf geranium

Bur clover

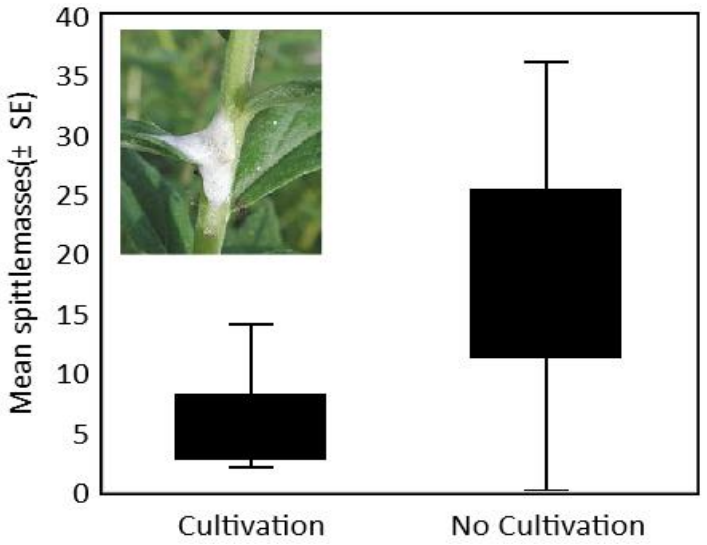
- nymphs prevalent on some common vineyard weeds
- may use some cover crops

Why more PD – a new(ly appreciated) vector?

NEXT STEPS:

- Additional monitoring of plant use by meadow spittlebug

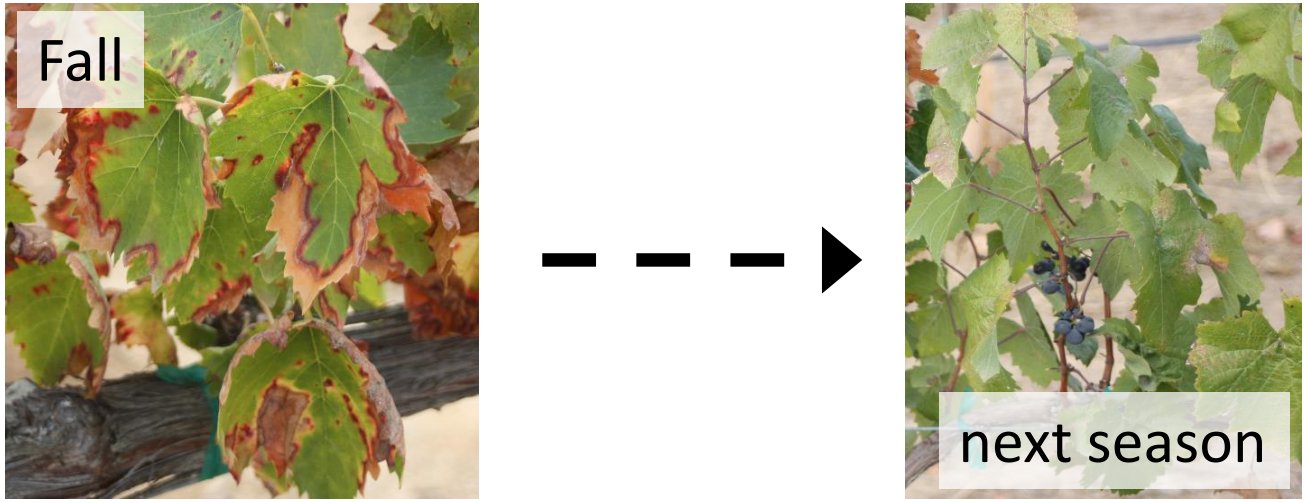
- Management (tilling) trials



- Monitoring and transmission trials for other potential vectors: *Aphrophora* sp., *Pagaronia* sp.

Why more PD – less over winter recovery?

Some diseased vines lose their infection over the winter

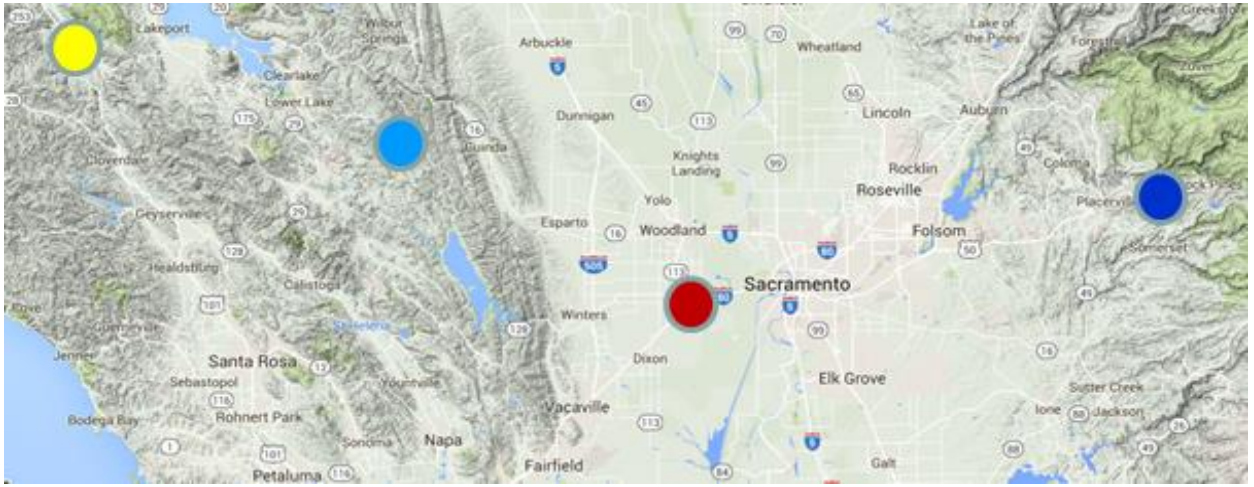


Mechanism of recovery is not completely understood

Recovery rate depends on: temperature, timing of infection, varietal

Recovery rate depends on local climate

- "cold curing" over the winter depends on # days below 40°F



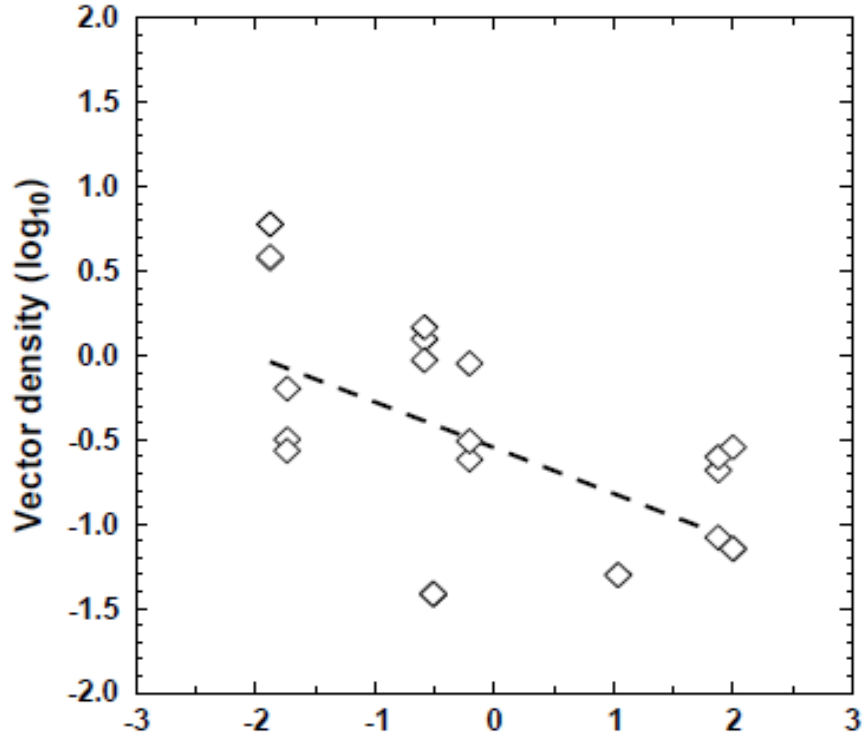
Lieth et al. 2012

		Levels of cold curing (C)			
		Pinot Noir		Cabernet Sauvignon	
Station name	Location (latitude, longitude)	2007–08	2008–09	2007–08	2008–09
Davis	N38°32′09″, W121°46′32″	0.44	0.50	0.00	0.00
Hopland	N39°00′25″, W123°04′45″	1.00	1.00	0.63	0.92
McLaughlin (Knoxville)	N38°49′40″, W122°20′26″	1.00	1.00	0.89	1.00
Foresthill (Camino)	N38°45′13″, W120°43′57″	1.00	1.00	1.00	1.00

Recent warm winters led to more chronic disease?

Why more PD – vector dynamics?

Warm, wet winters favor higher BGSS population densities



warm, wet winter

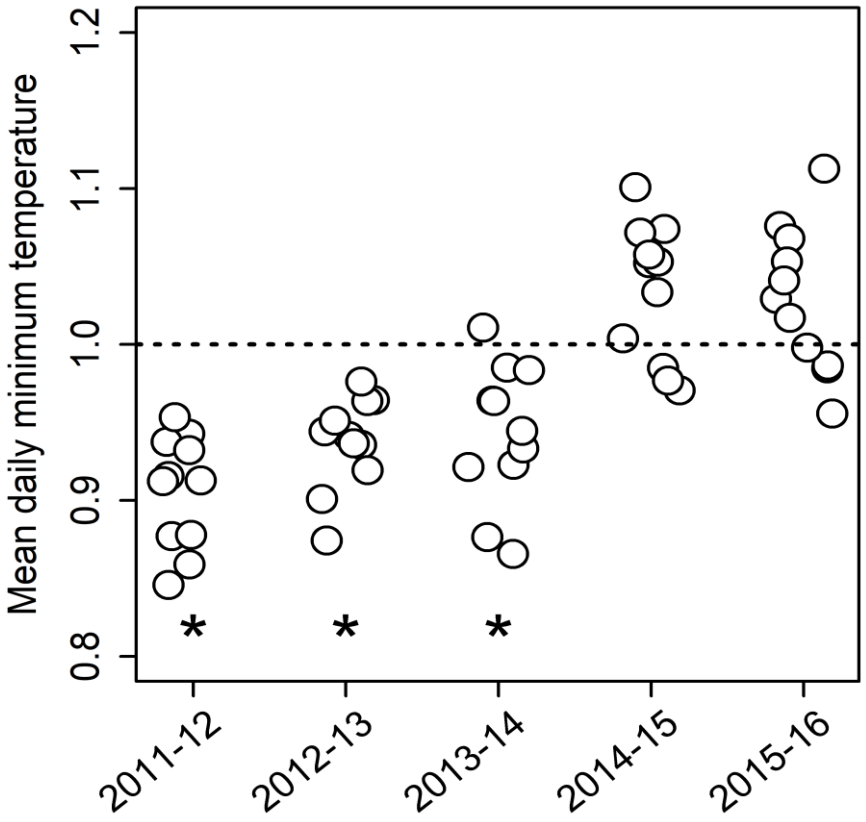
cold, dry winter

El Nino = bad, La Nina = good?

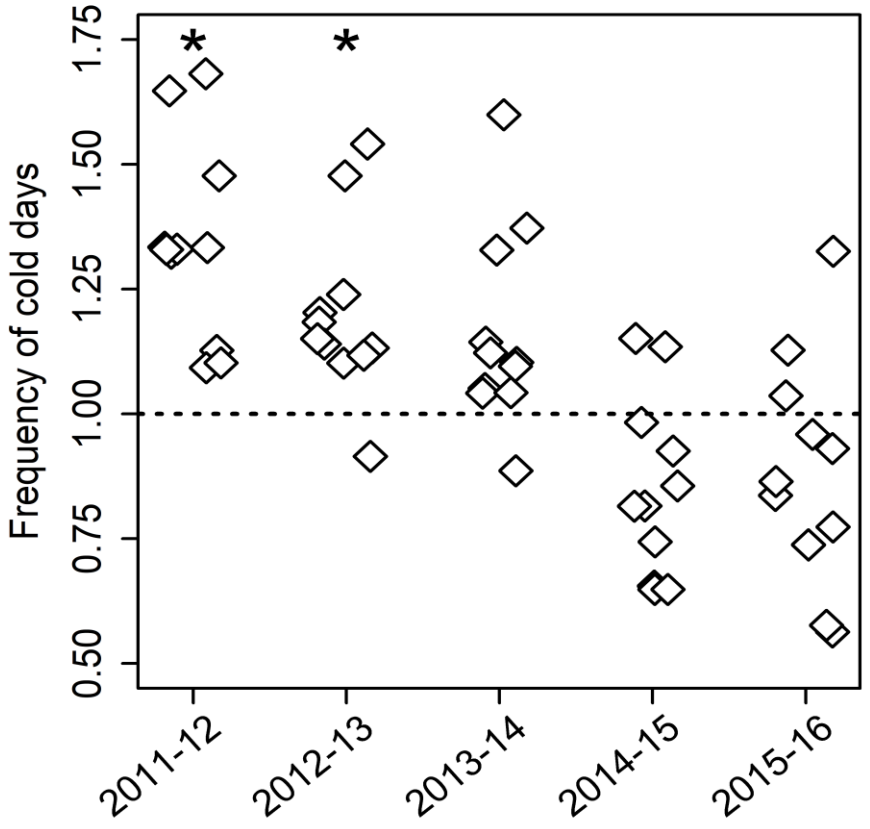
Why more PD – warmer winters?

Comparison of recent versus historic climate data

Avg. winter lows



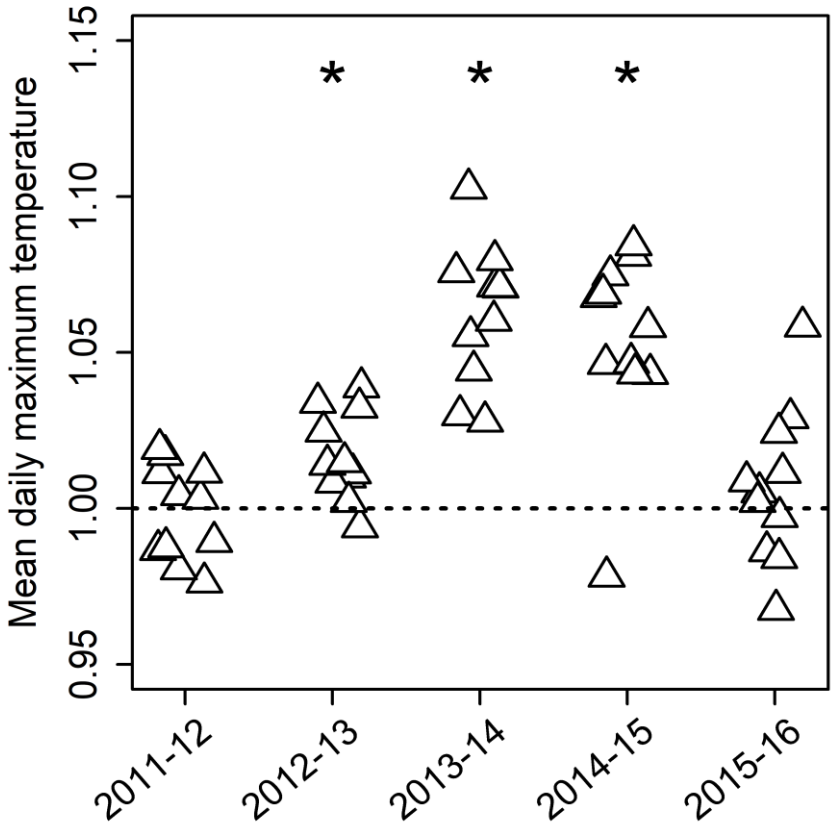
of “cold” days



Recent winter temperatures don’t stand out as being noticeably “less cold” than historic averages

Why more PD – warmer winters?

Comparison of recent versus historic climate data



Avg. winter highs

Daily high temperatures were higher 2012-15

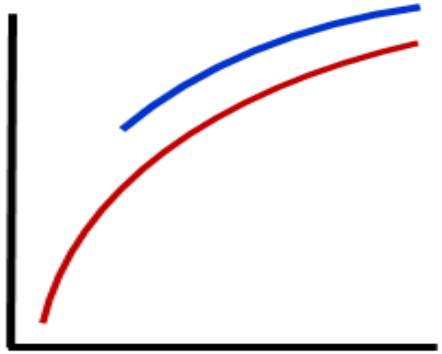
Greater BGSS populations or activity?

Why more PD – warmer winters?

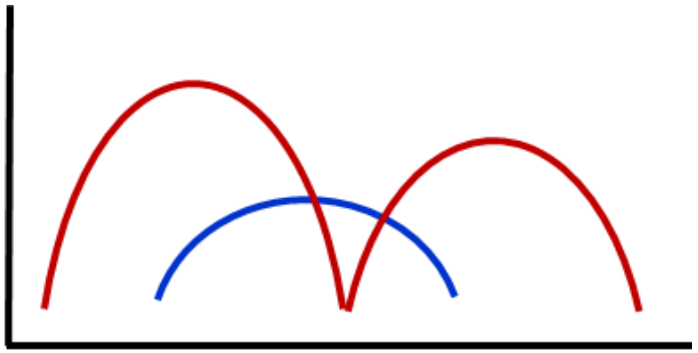
Comparison of recent versus historic climate data

NEXT STEPS:

1. Vector activity earlier in the season? (earlier inoculations = less overwinter recovery)



2. Longer “season” of vector activity? (more potential for secondary spread)



Factors that aid/undermine PD management

+ vectors must acquire from infected plant to be infective

+ pruning is not an important source of *Xylella* spread

+ no evidence of root-graft transmission

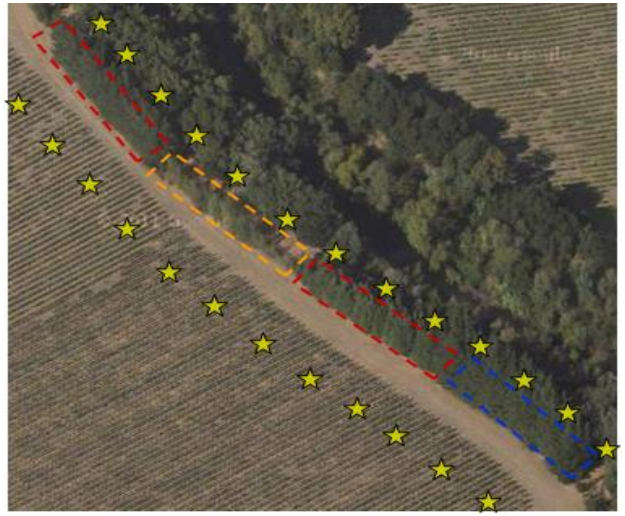
+ cold winters encourage recovery of some vines

- can't prune out PD infections

- resistant/tolerant varieties not yet available

- no therapeutic cure for infected vines

PD management relies on 1) suppressing vector populations and 2) limiting pathogen supply



PD management in the coast range

Vector monitoring

Biological control **?**

Barriers to sharpshooter movement **?**

Prune out infections**?** (not effective)

Chemical control

Weed management

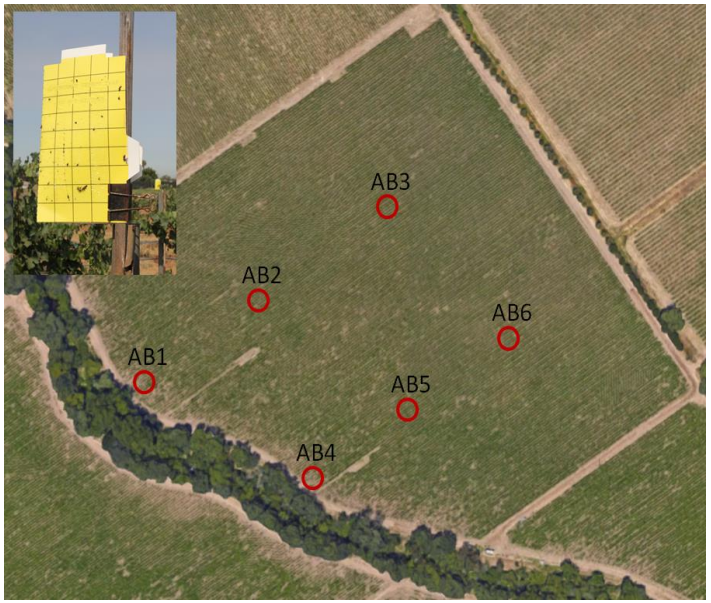
Vine roguing **?**

Riparian management

Monitoring for sharpshooters

Monitoring is important for identifying location and timing of insecticide applications

1. Deploy sticky traps near edge or in transects away from source habitat
    - riparian + ornamentals for BGSS
    - check traps twice a month, or more often in the Spring
2. Sweep-net sampling on vineyard floor and surrounding edges
    - esp. areas with weedy grasses



Limited role for biological control of BGSS

Parasitoids play an important role in management of some sharpshooters

- GWSS egg parasitoids

Some common generalist predatory arthropods attack sharpshooters

Insectivorous birds have been encouraged for BGSS control

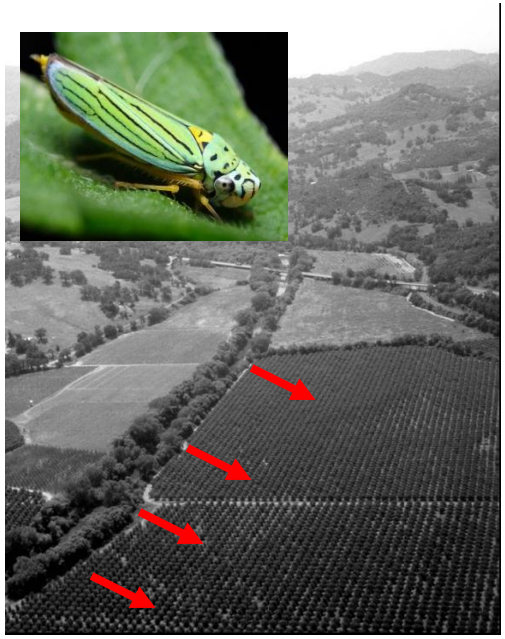
May help, but effect isn't likely to be enough to reduce PD

Disrupting BGSS movement into vineyards

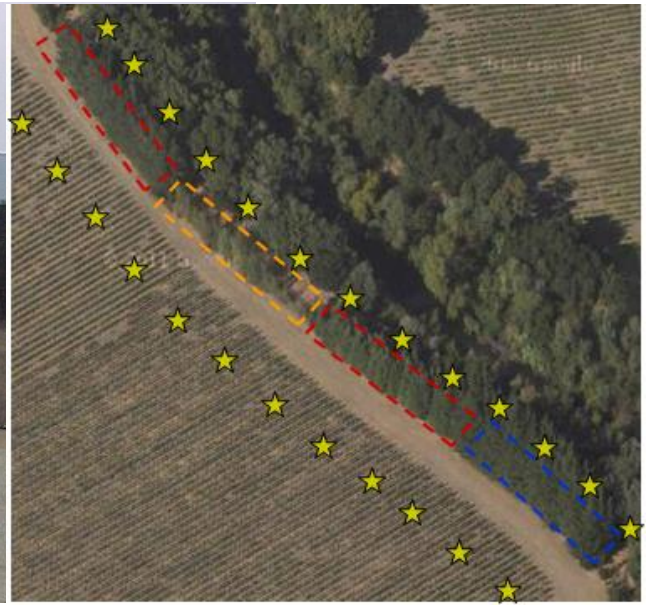
Sharpshooters are not great fliers

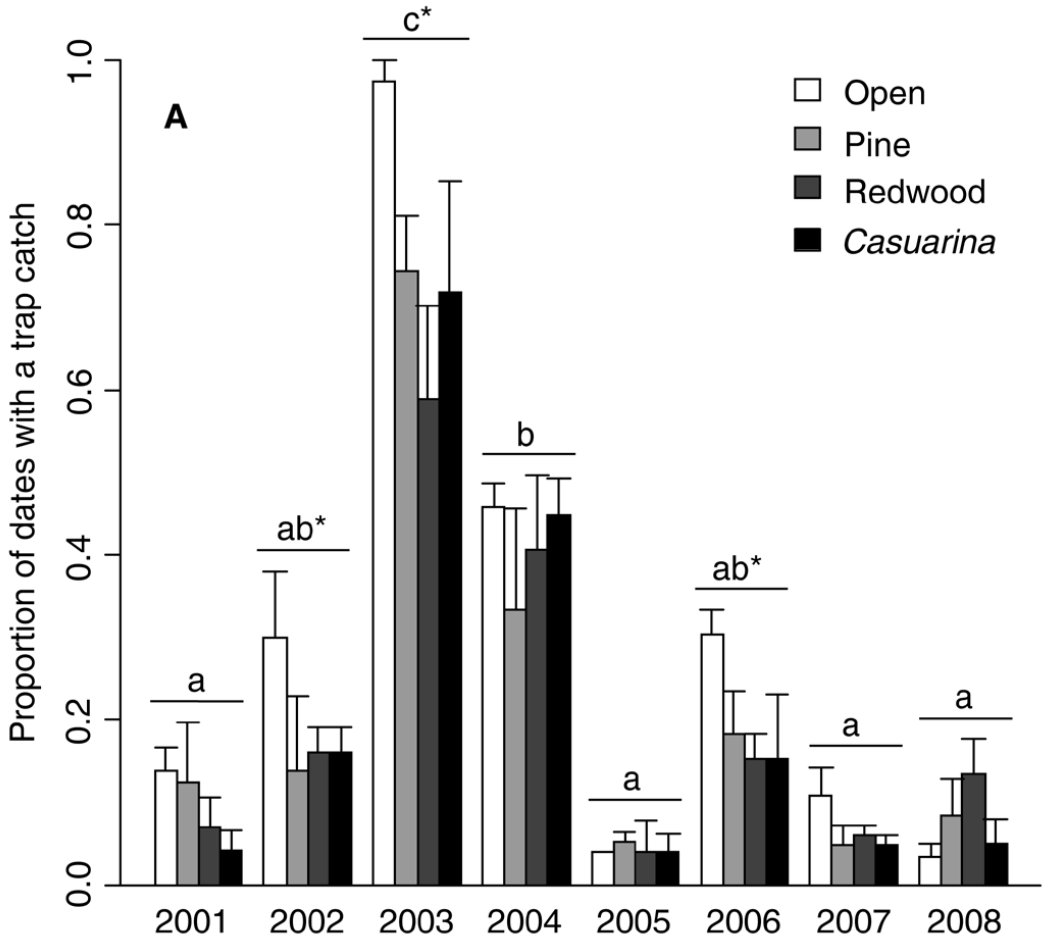
Most BGSS fly close to the ground
(90% <5m)

Can a barrier between riparian and vineyard reduce incursion into vineyards?



- artificial barrier
- green barrier with non-host plants





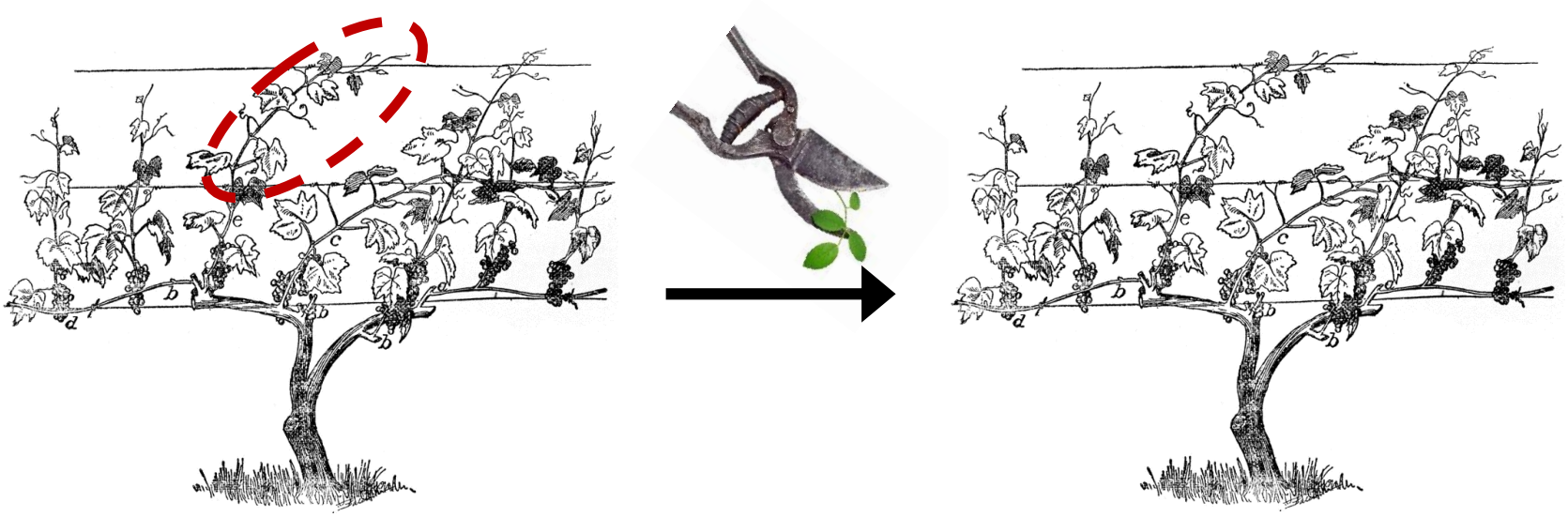
In 3 of 8 years BGSS were caught less frequently in vineyards next to barrier plantings

Best case was a 50% reduction for redwood barrier, but most often there was no effect

“pruning out” *Xylella* infection is impractical

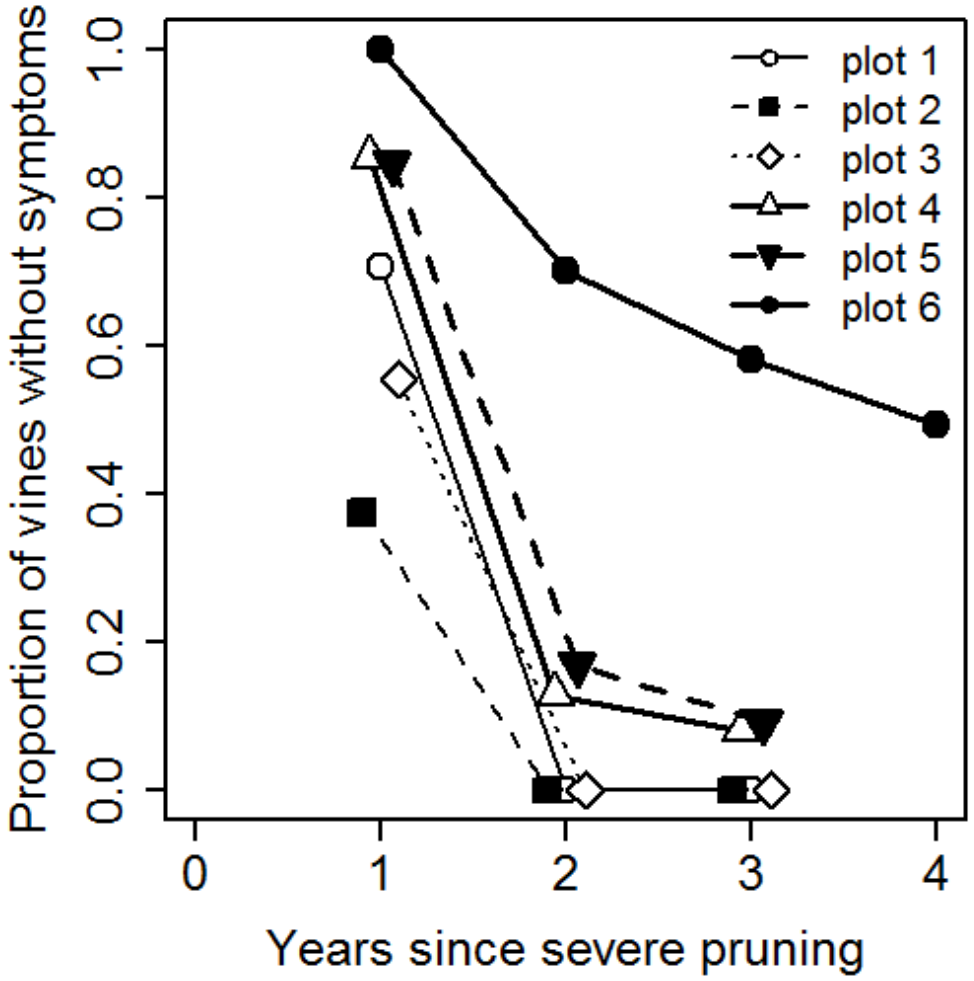
Xylella infections can be “patchy” within vines, especially early on

Can aggressive pruning clear vines of infection?



Pruned slightly above graft union, grafted on healthy shoot

Monitored disease in subsequent years



1 yr after severe pruning the results looked promising

By 2 yr majority of vines were again showing PD in 5 of 6 plots

Chemical control of GWSS

Insecticides for sharpshooter control include conventional systemics and foliars, and organics http://www.ipm.ucdavis.edu/PMG/r302301711.html

Common name (Example trade name)	Amount per acre**	R.E.I.‡ (hours)	P.H.I.‡ (days)

UPDATED: 7/15

Compare treatments | Calculate emissions | Protect bees

The following are ranked with the pesticides having the greatest IPM value listed first—the most effective and least harmful to natural enemies, honey bees, and the environment are at the top of the table. When choosing a pesticide, consider information relating to air and water quality, resistance management, and the pesticide's properties and application timing. Not all registered pesticides are listed. Always read the label of the product being used.

A.	IMIDACLOPRID			
	(Admire Pro - Soil)	7–14 fl oz	12	30
	(Admire Pro - Foliar)	1.0–1.4 fl oz	12	0
	COMMENTS: Foliar imidacloprid kills sharpshooters fast but only for about 2 weeks. Soil-applied imidacloprid provides a slower kill, but remains effective longer. To protect honey bees, apply foliar sprays only during late evening, night, or early morning when bees are not present.			
B.	CLOTHIANIDIN			
	(Belay - Soil)	12 fl oz	12	30
	(Belay - Foliar)	4–6 fl oz	12	0
	MODE-OF-ACTION GROUP NUMBER[1]: 4A			
	COMMENTS: Soil moisture is important for effective soil application; follow label instructions carefully. For foliar application, to protect honey bees, apply only during late evening, night, or early morning when bees are not present. Do not spray directly nor allow drift onto blooming crops or weeds where bees are foraging.			
C.	ACETAMIPRID			
	(Assail 70WP)	1.1 oz	12	3
	MODE-OF-ACTION GROUP NUMBER[1]: 4A			
	COMMENTS: To protect honey bees, apply only during late evening, night, or early morning when bees are not present.			

Chemical control – conventional insecticides

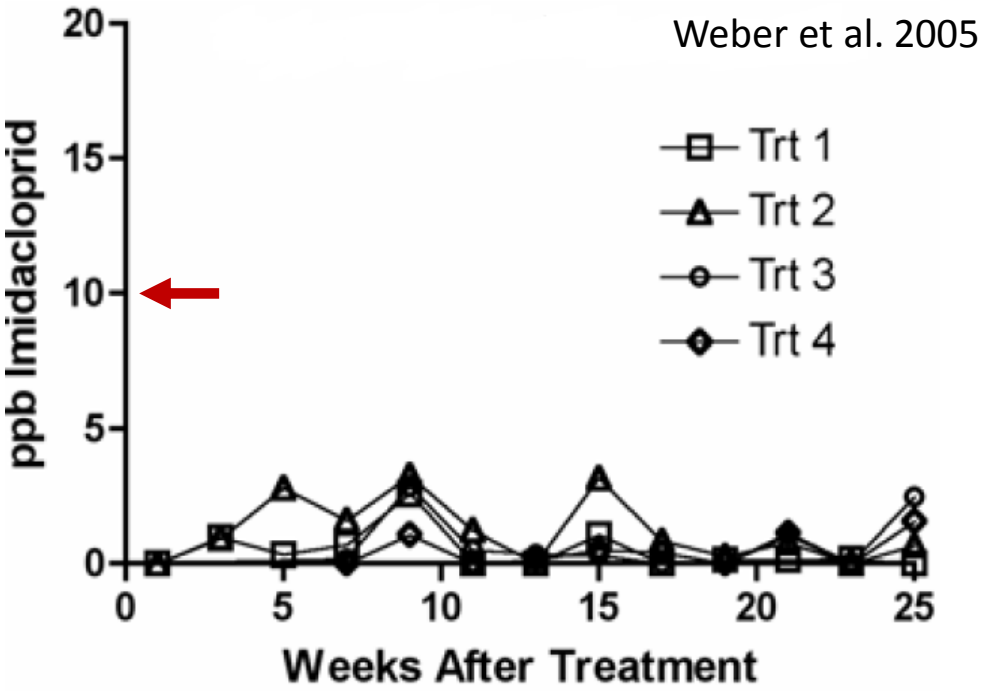
Soil application of systemic neonicotinoid (Spring?):

- imidacloprid, thiamethoxam, dinotefuran, clothianidin
- high mortality at 10 ppb in xylem; anti-feedant effect
- long residual efficacy (months)

Foliar applications (targeting Spring, mid-Summer BGSS peaks):

- acetamiprid, fenpropathrin, clothianidin
- timing based on monitoring
- moderate residual efficacy (weeks)
- postharvest interval important consideration later in season

More clay-rich soils and limited watering minimize uptake of some systemic insecticides in the North Coast



- Imidacloprid: < 2 % of samples ever reached 10 ppb
- Dinotefuran preferred? (more soluble)

Chemical control – organics insecticides

<u>pyrethrins</u>

- very short residual efficacy (contact)
- retreat on 7 – 10 d basis, based on monitoring

<u>kaolin clay</u>

- reduces attraction to plant, disrupts feeding, reduces oviposition
- retreat on 1 - 3 wk basis, based on monitoring

Weed control in and around vineyards

Common weedy grasses can be vector sources

- irrigation/roadside ditches, leaky irrigation
- Bermuda grass
- green, red-headed sharpshooter

Several weeds are *Xylella* reservoirs

- morning glory, poison hemlock, prickly lettuce, Datura, mustards, broom

Removal of diseased vines

Roguing diseased vines ensures they aren't a pathogen source

Scout for disease in the Fall, when symptoms are strongest

Flag vines showing extensive, convincing set of PD symptoms for later removal

Note questionable vines and follow them the next season.

Riparian vegetation management

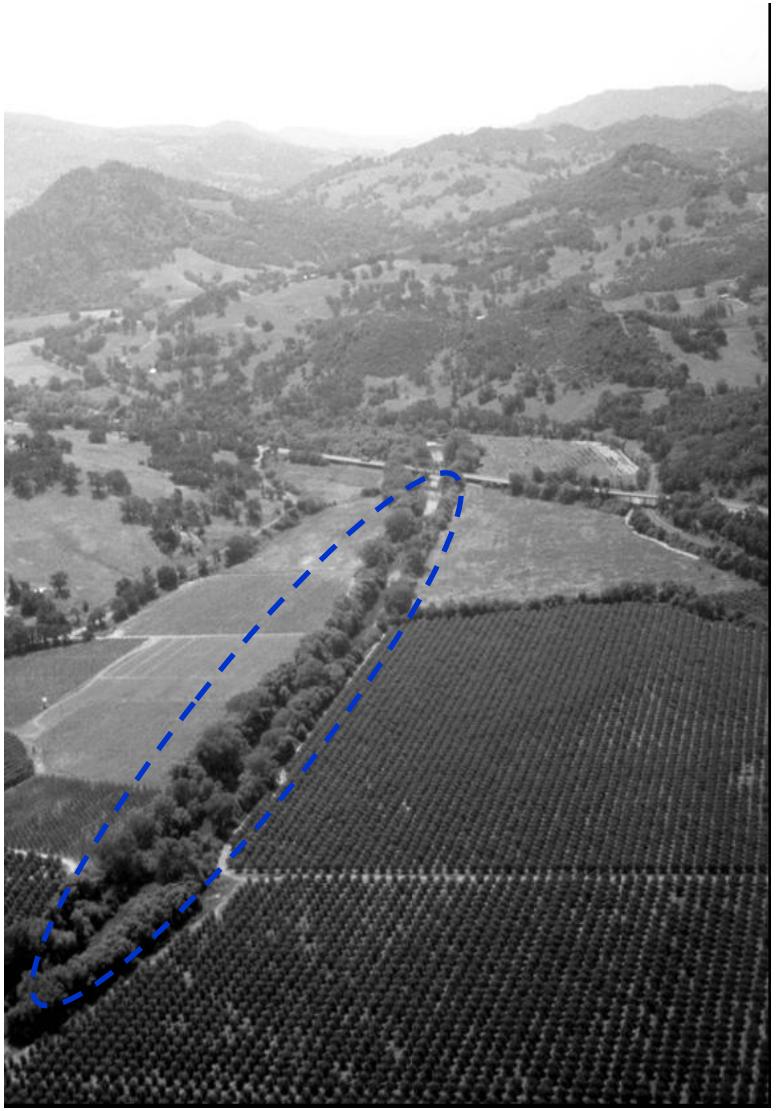
Riparian corridors are a key source of BGSS

Management involves targeted removal of key hosts plants

Removal of reproductive hosts can dramatically reduce BGSS density

- by upwards of 90%
- more effective than insecticides

Removal may also reduce pathogen supply



Key host plants:

Non-native host plants

Common name	Latin name
Himalayan blackberry	*Rubus discolor*
periwinkle	*Vinca major*
wild grape (escaped cultivar or *Vitis californica* hydrid)	*Vitis sp.*

Native host plants

Common name	Latin name
California blackberry	*Rubus ursinus*
California grape	*Vitis californica*
mugwort	*Artemisia douglasiana*
stinging nettle	*Urtica dioica*
mulefat	*Baccharis salicifolia*
blue elderberry	*Sambucus mexicana*

Riparian vegetation management manual:

https://nature.berkeley.edu/xylella/control/PDNorthCoast/

Long-term management strategy

- permitting by CDFW

Requires vigilance to continue to reap benefits

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Entomology

http://www.cnr.berkeley.edu/xylella/

http://www.ipm.ucdavis.edu/PMG/r302301711.html

http://www.piercesdisease.org/

http://www.cdfa.ca.gov/pdcp/