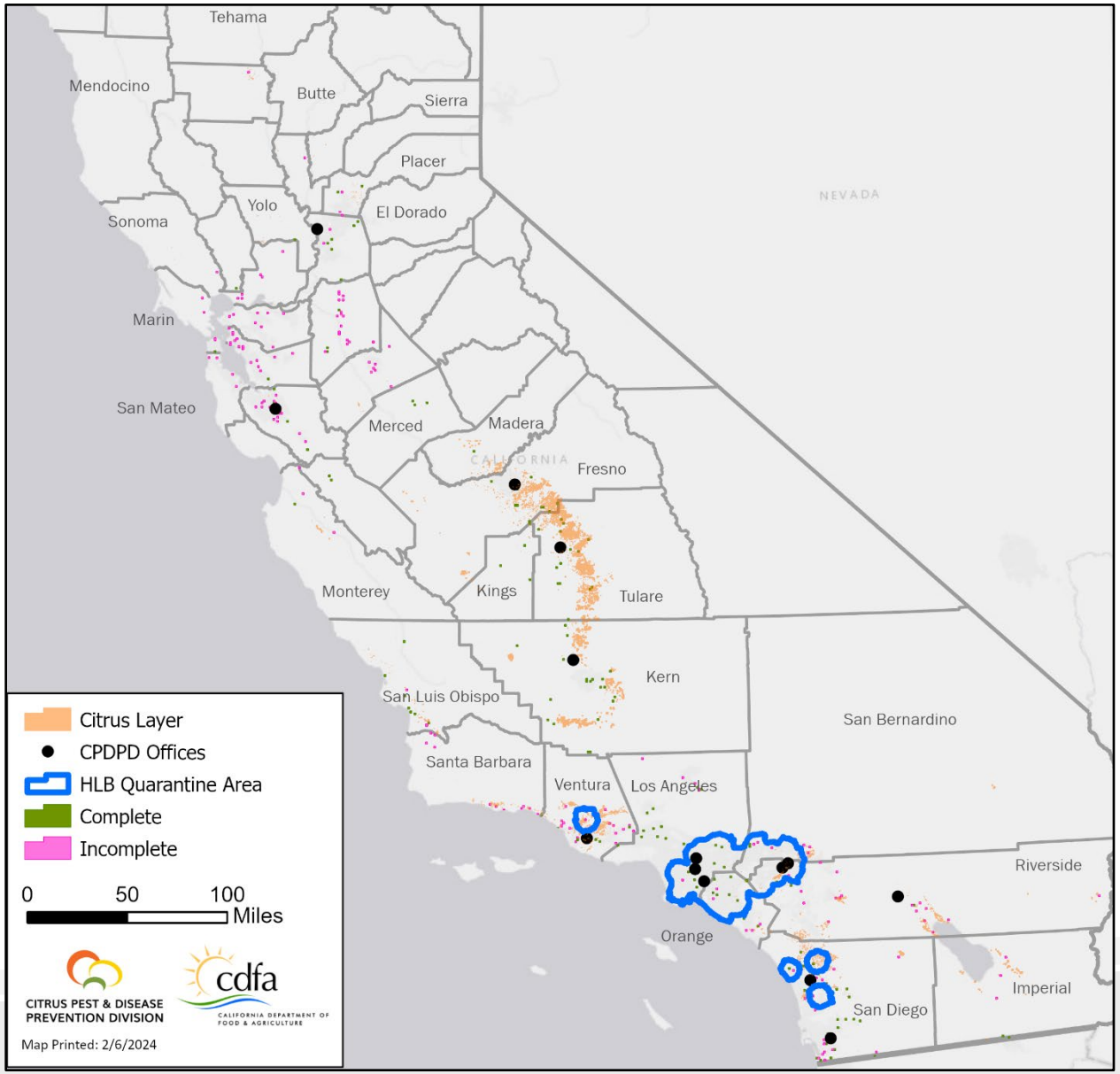
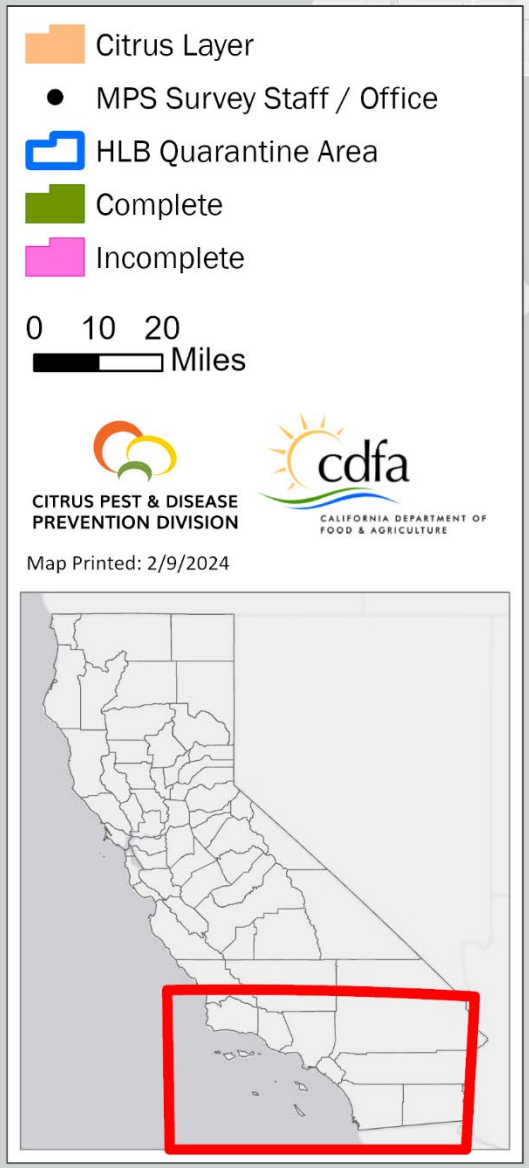
Multi-Pest Survey Update
Science Subcommittee Meeting
February 14, 2024

2023 Cycle 2



- Began August 2023
- 46% Complete
- Survey Complete in 9 of 34 Allocated Counties
- 5,747 Properties Surveyed
- 1,649 Properties Sampled
- 679 Entomology PDRs
- 1,185 Plant PDRs

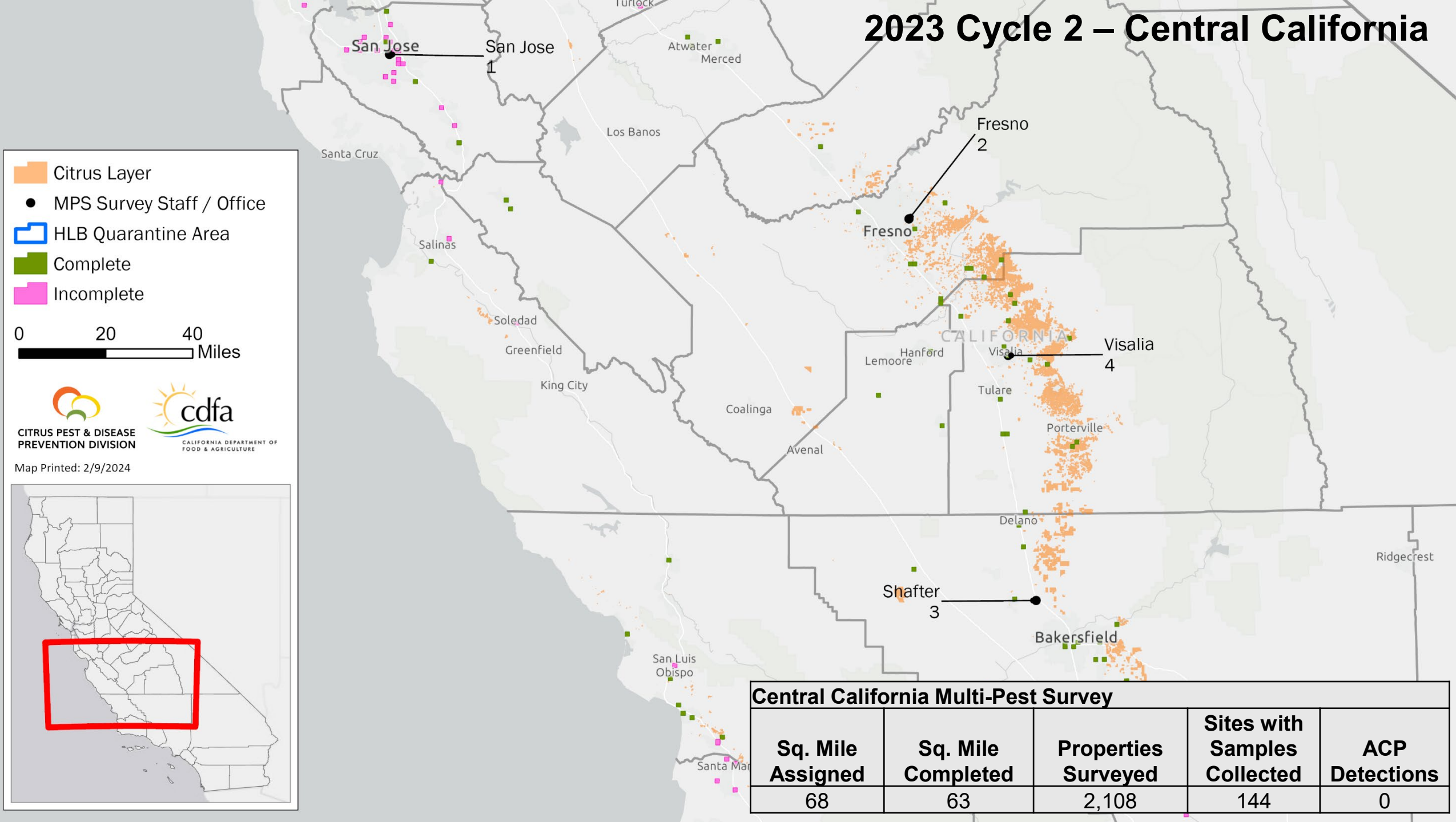
2023 Cycle 2 – Southern California



2023 Cycle 2 – Southern California

Southern California Multi-Pest Survey					
Areas	**Sq. Mile Assigned**	**Sq. Mile Completed**	**Properties Surveyed**	**Sites with Samples Collected**	**CLas+ ACP and HLB Detections**
Quarantine Edge	5	4	153	88	0
Grove Buffer	80	26	773	449	12
Outside Quarantine[1]	54	27	1,003	423	0
Within Quarantine[1]	17	12	761	532	45
Total	**156**	**69**	**2,690**	**1,492**	**57**
1. Do not include areas already counted under the “quarantine edge" and "grove buffer" categories.					

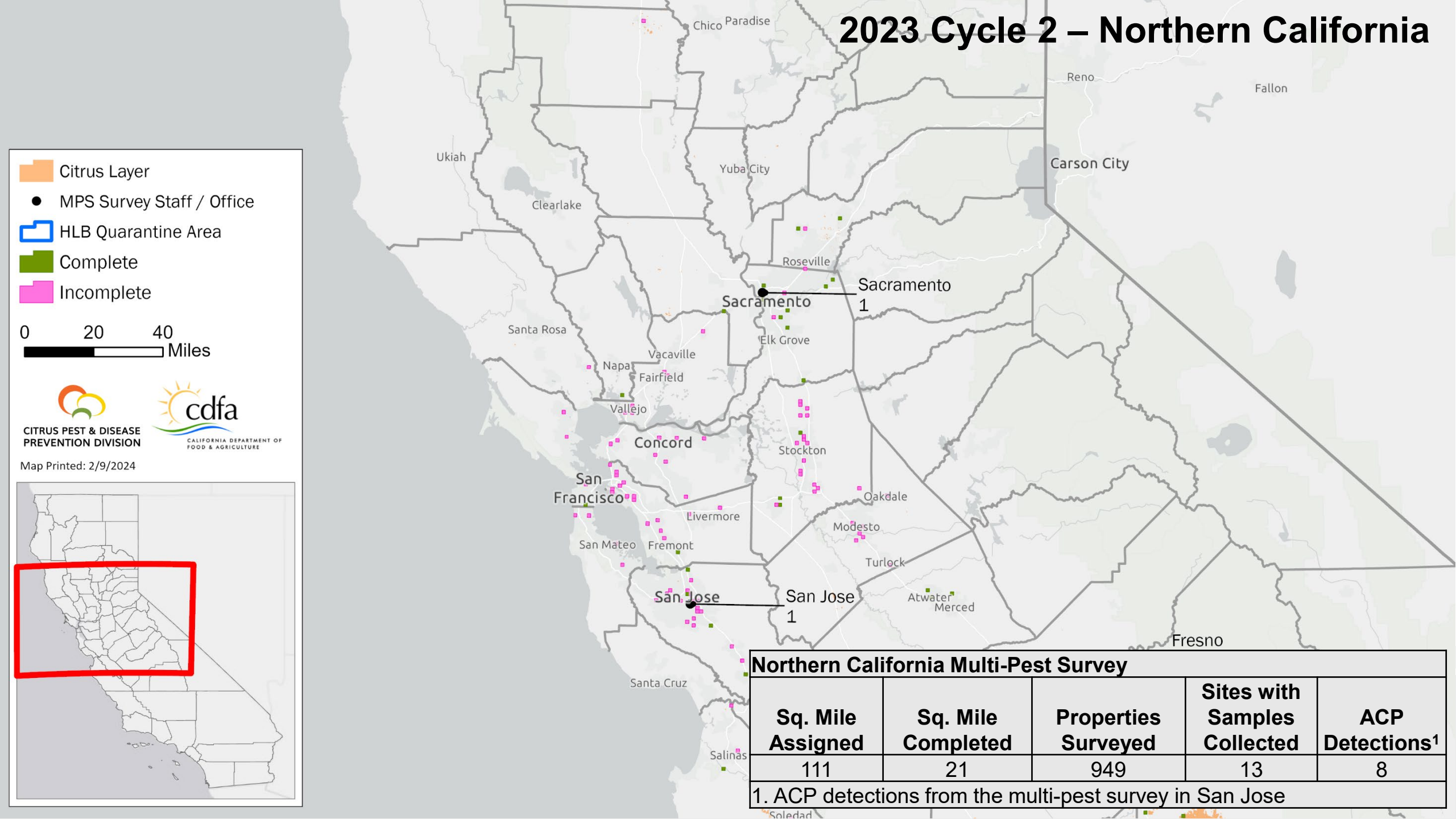
2023 Cycle 2 – Central California



Central California Multi-Pest Survey

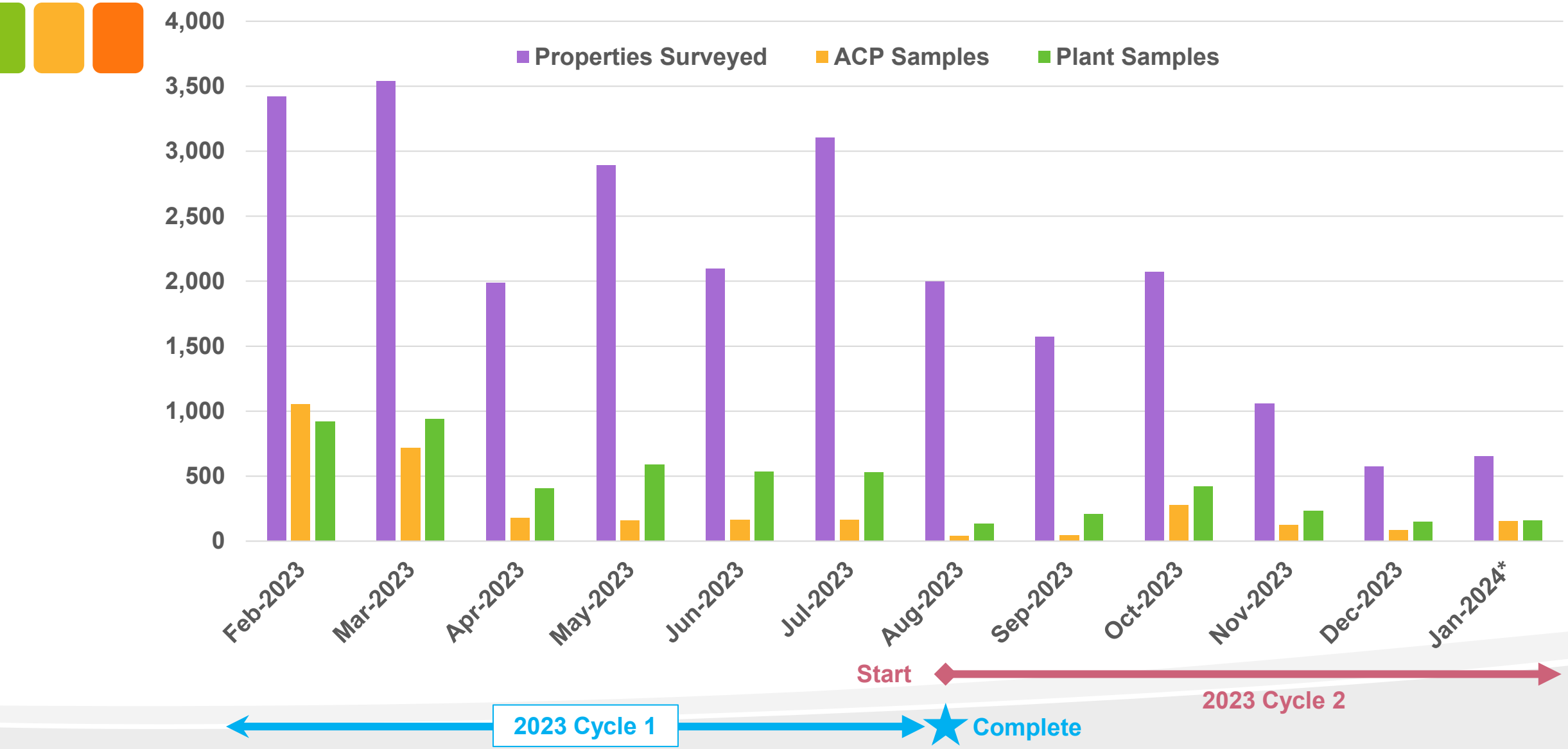
Sq. Mile Assigned	Sq. Mile Completed	Properties Surveyed	Sites with Samples Collected	ACP Detections
68	63	2,108	144	0

2023 Cycle 2 – Northern California



Northern California Multi-Pest Survey				
Sq. Mile Assigned	Sq. Mile Completed	Properties Surveyed	Sites with Samples Collected	ACP Detections[1]
111	21	949	13	8
1. ACP detections from the multi-pest survey in San Jose				

Statewide Trends (All Cycles)



*January data is being finalized

EcoData

February 14, 2024

2024 Updated Analysis on Residential Tree Removals for HLB

Presented to CPDPC Science Subcommittee
By Rob Clark, Ph.D. - Founder, EcoData Technology

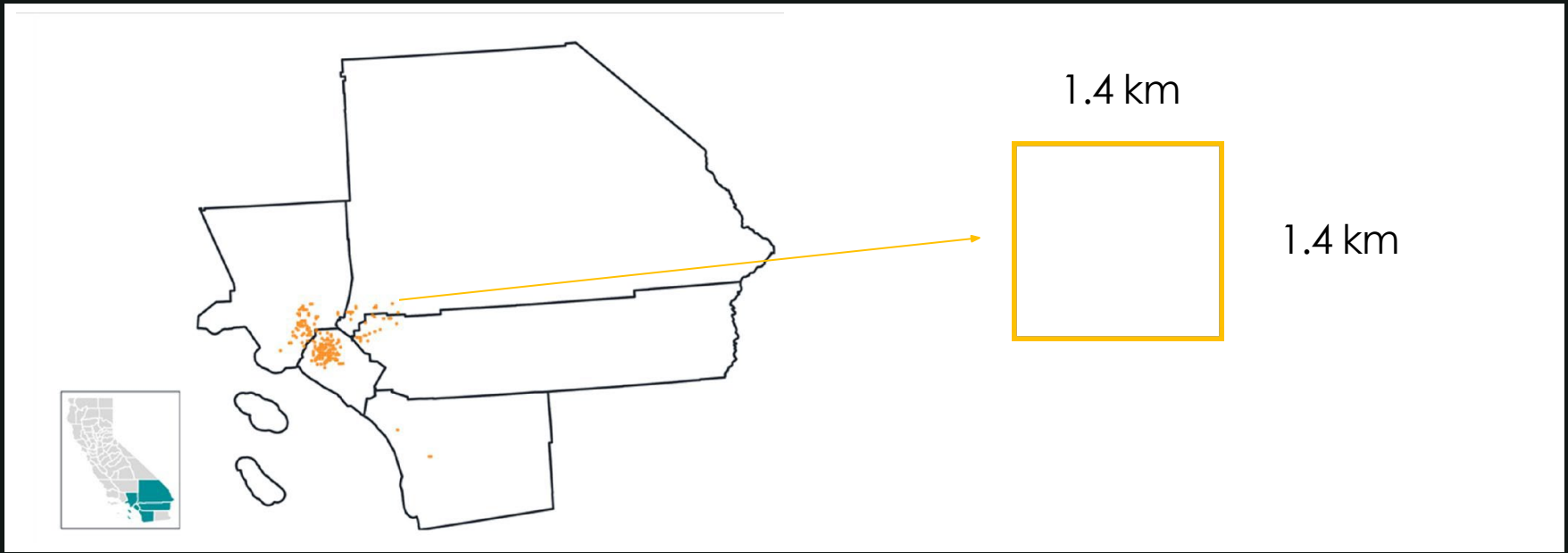
Summary

- I am currently analyzing data relevant to residential tree removals in California

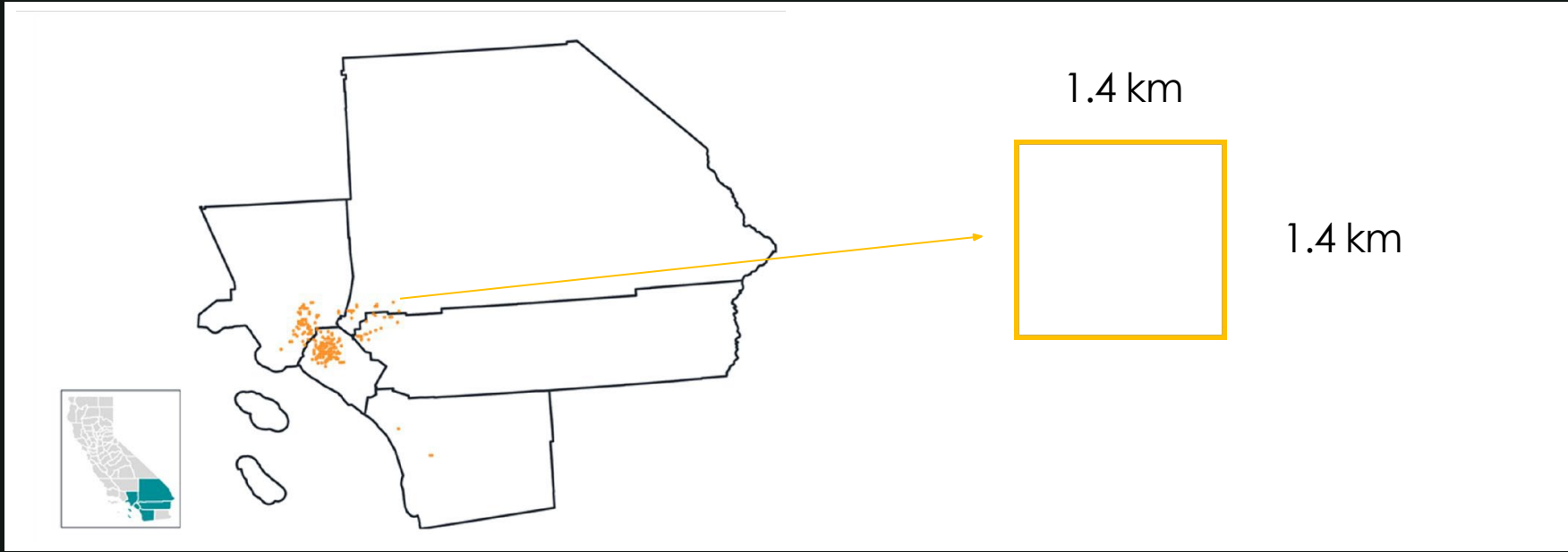
- The goal is to quantify the impacts of residential tree removals in order to best advise on HLB management practices

- Today's presentation goes over the most recent findings on the local impacts of tree removals

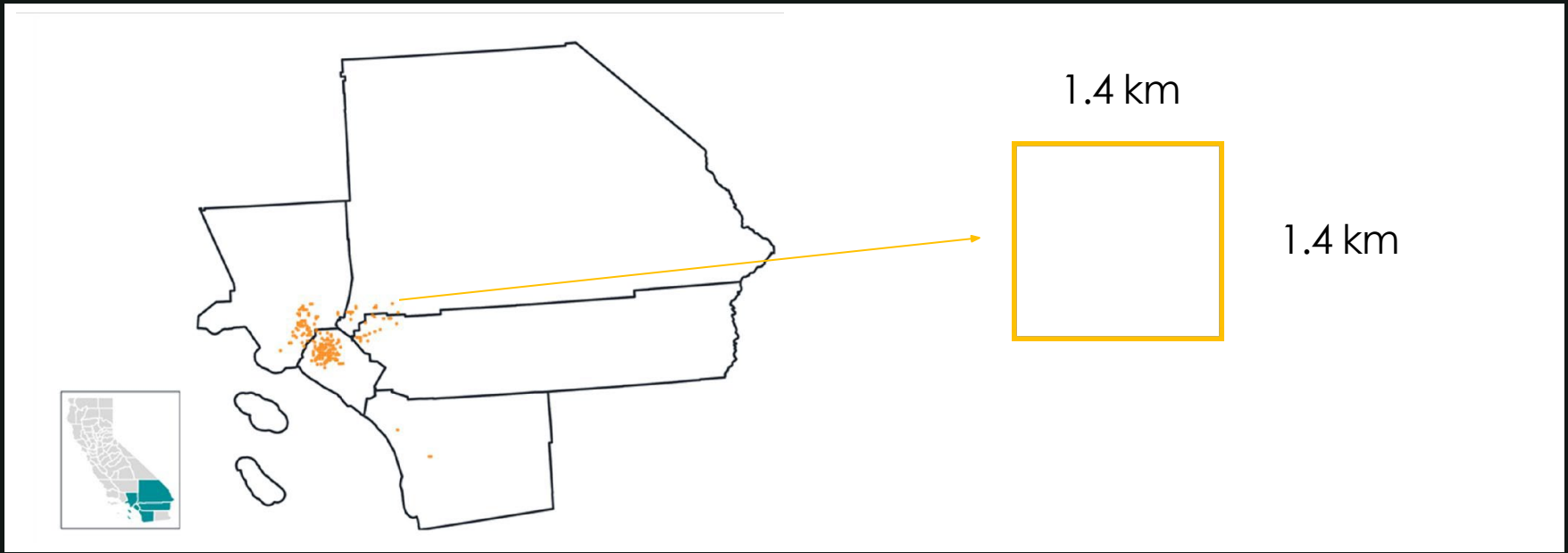
The current analysis looks at the local effect of tree removals in 1.4 x 1.4 km gridded locations (cells)



These cells are selected since they are locations where CLas+ trees have been removed, but then there were more subsequent detections of CLas+ trees



In some locations, tree removals typically take place quickly (<40 days), while in others they take longer (>40 days)



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EcoData

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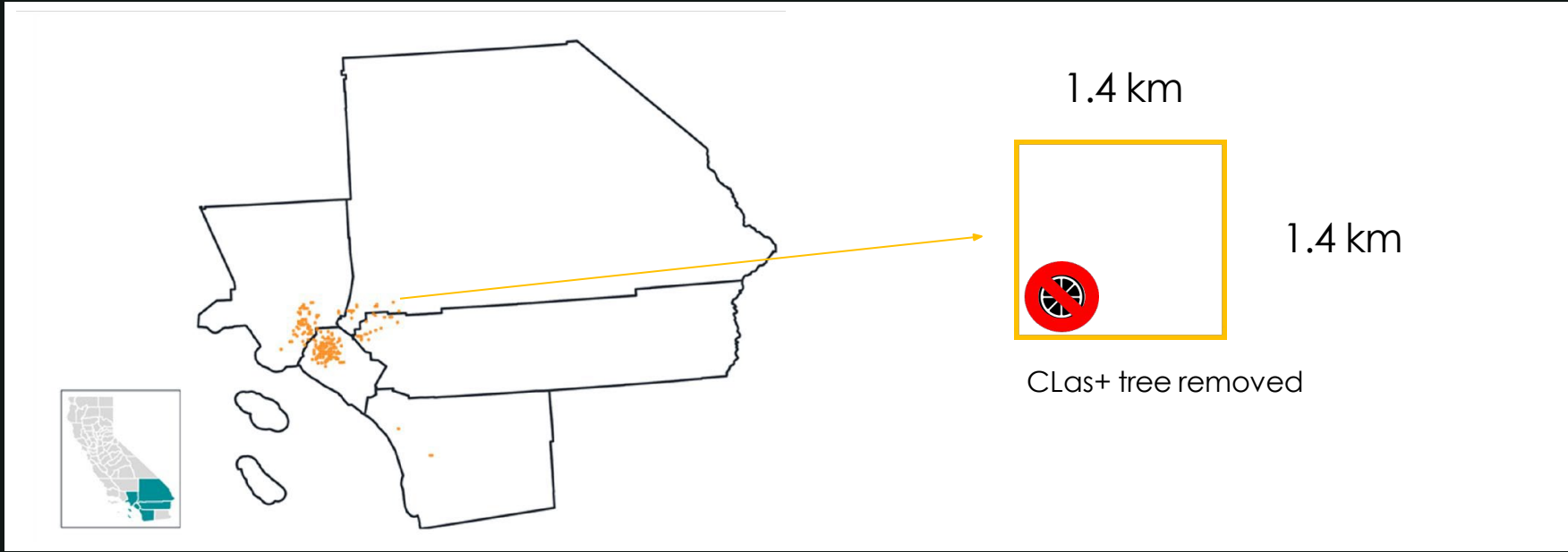

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In some locations, tree removals typically take place quickly (<40 days), while in others they take longer (>40 days)

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Question 1: Is there less inoculum in locations where tree removals happen quickly?

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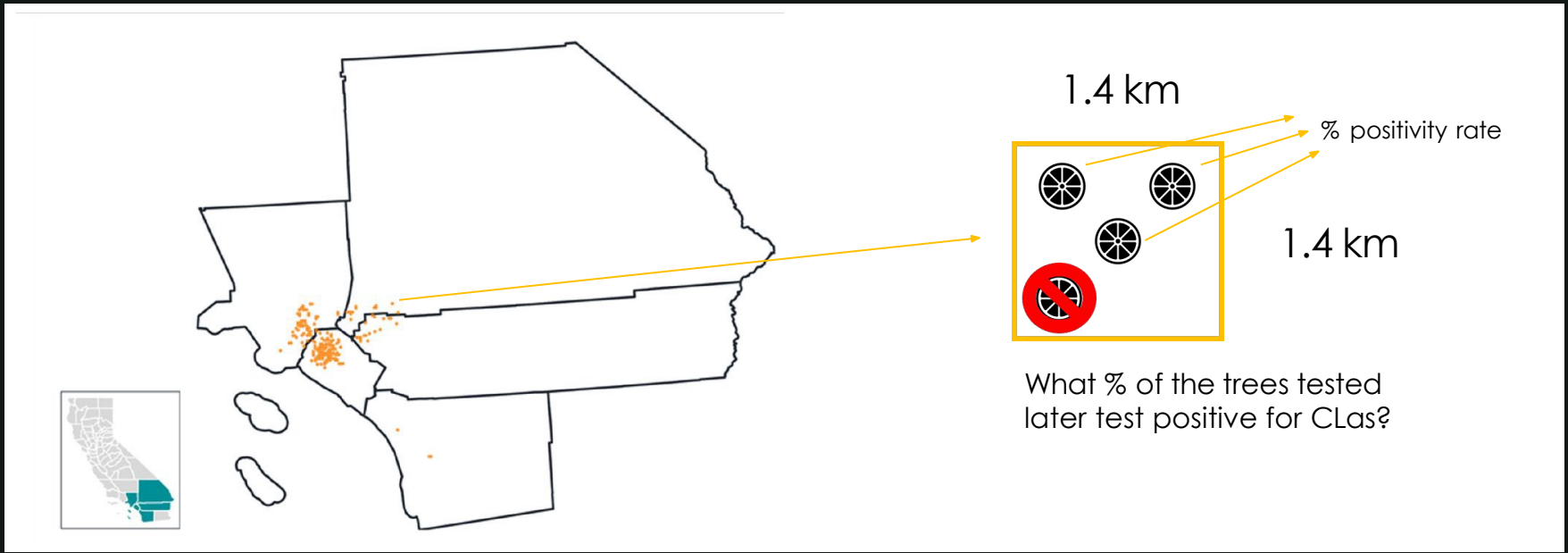
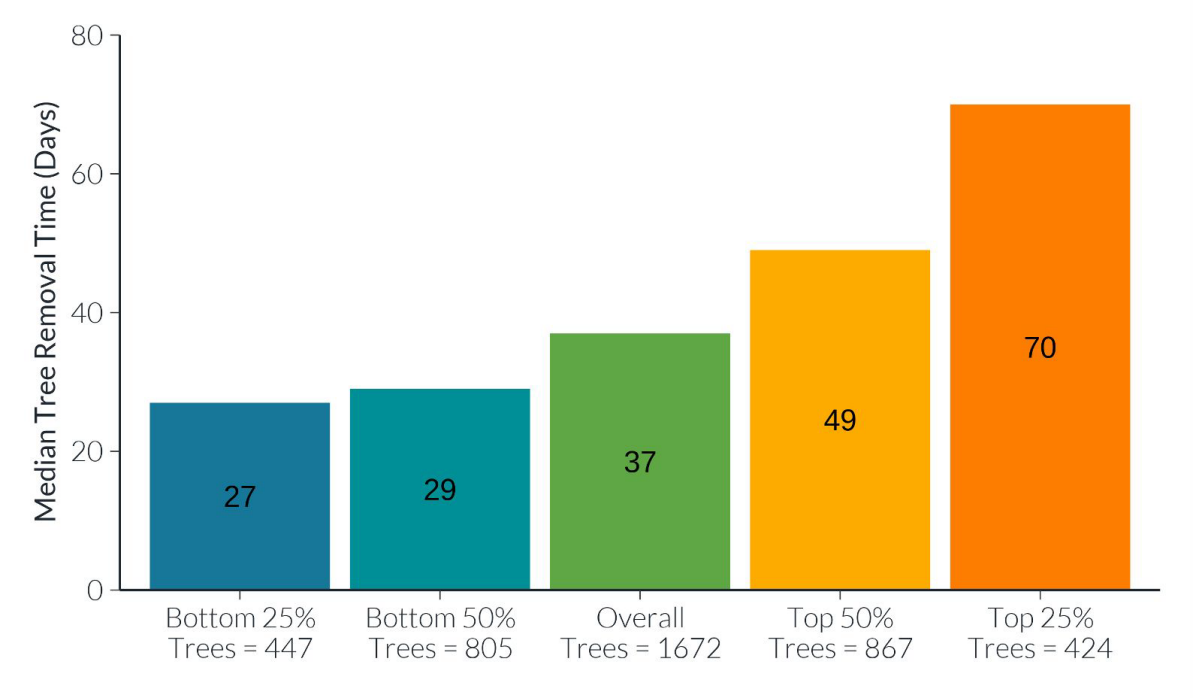
Question 2: Is the proportion of CLas+ trees lower where tree removals happen quickly?



The time between plant tissue sampling and removal of CLas+ positive trees ranges from 27 to 70 days in residential surveys, providing enough variation for a statistical analysis



EcoData

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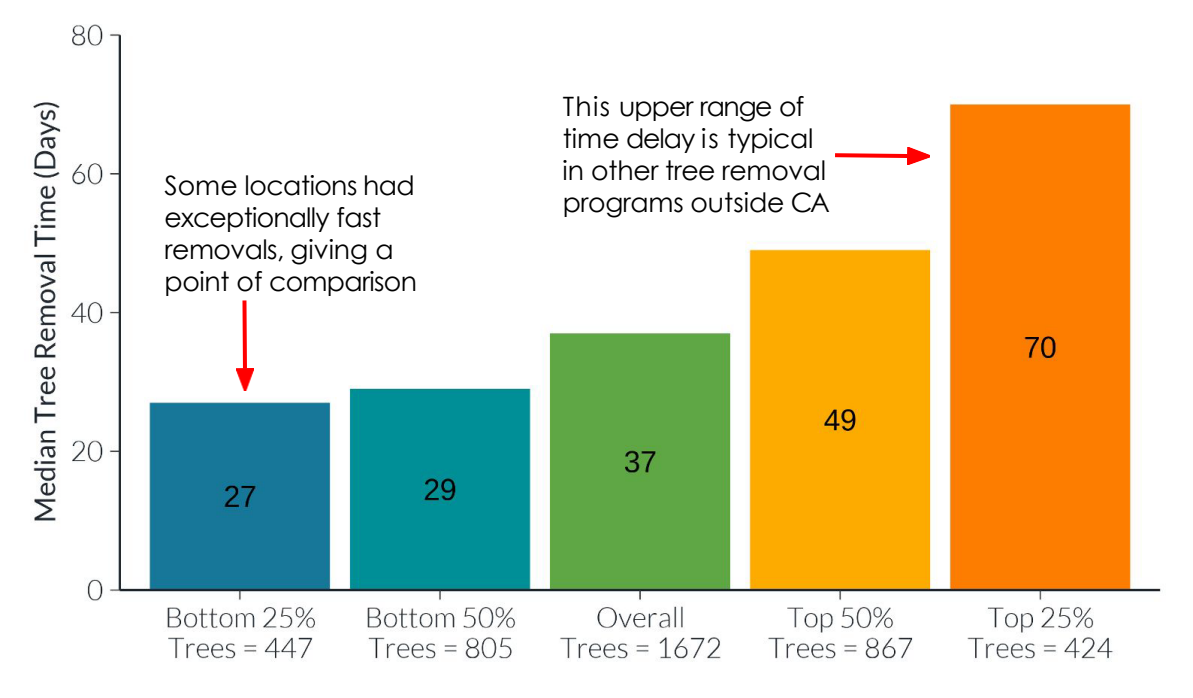

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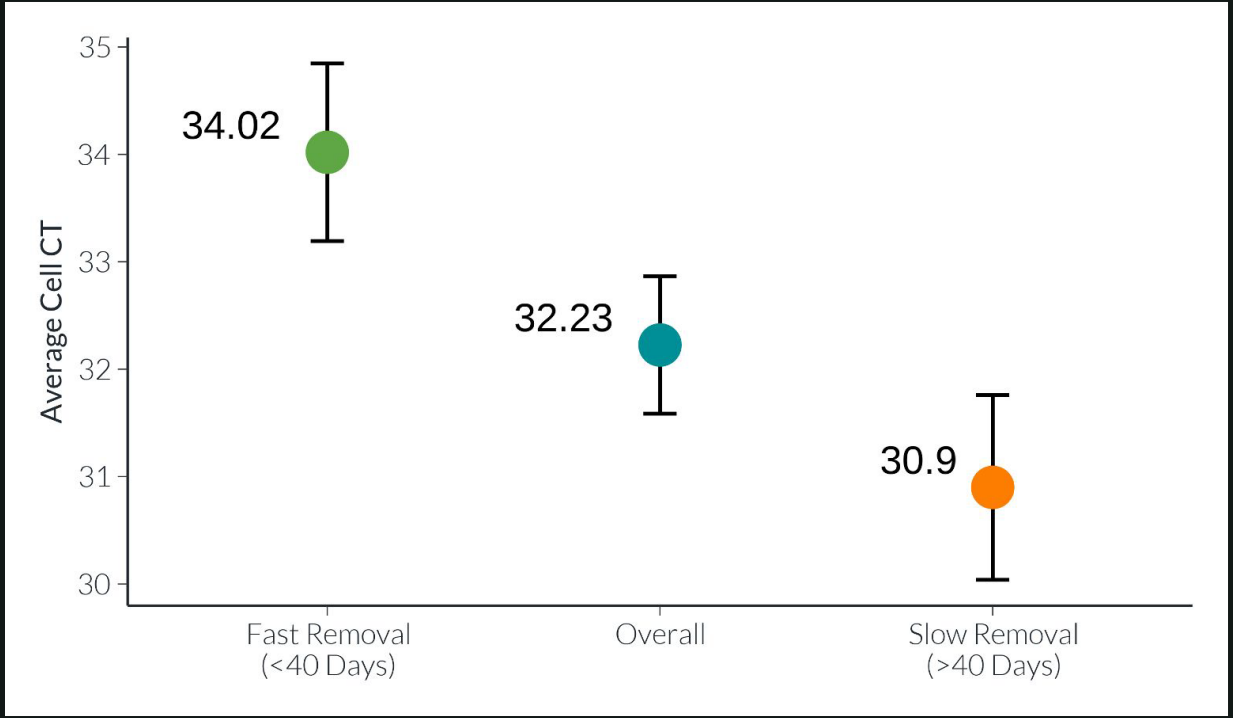
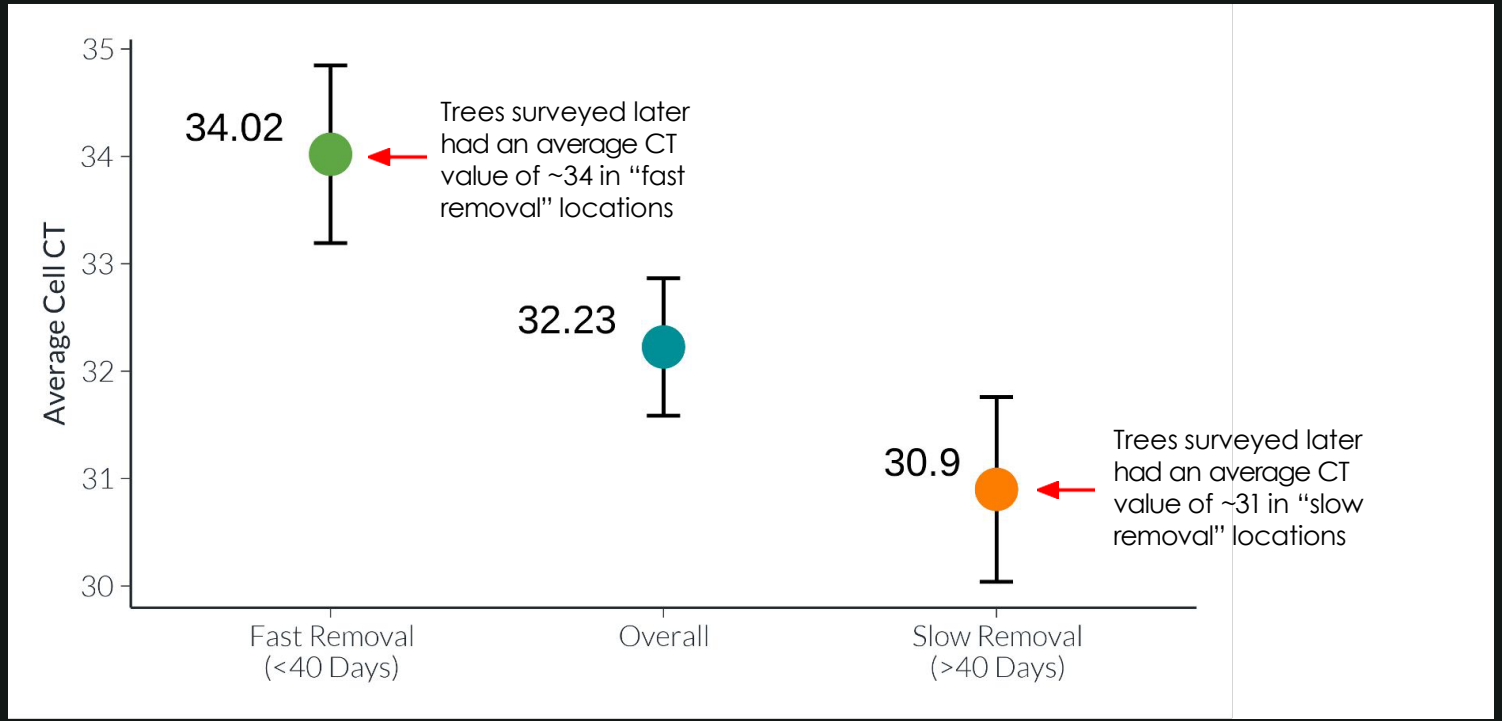
Q1: Assuming CT are an indicator of inoculum levels, fast tree removal locations (1.4 km^2 grids) have higher CT values in subsequent CLas+ detecctions.



CT values are not perfect indicators of inoculum levels for HLB, but a CT value difference of ~3 is notable since it suggests there is more CLas in slow removal locations



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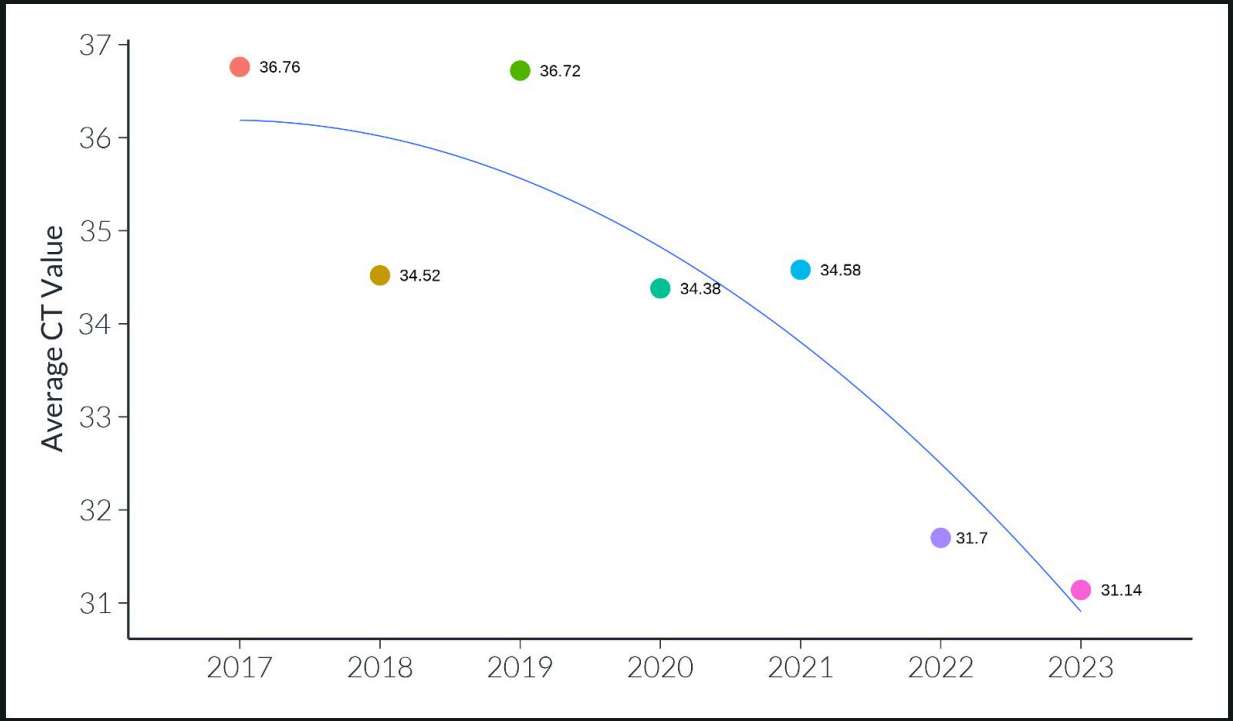
Note: CT values have consistently declined since 2017 as part of the typical development of a pathogen reservoir. The analysis presented here accounts for year effects, but not other factors.



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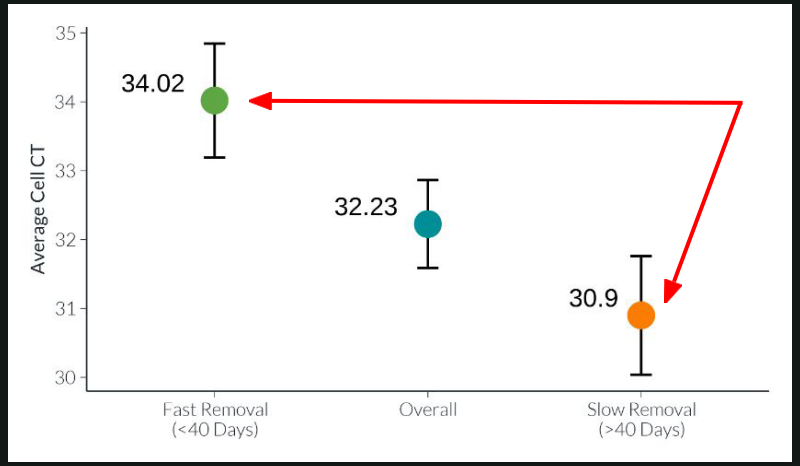

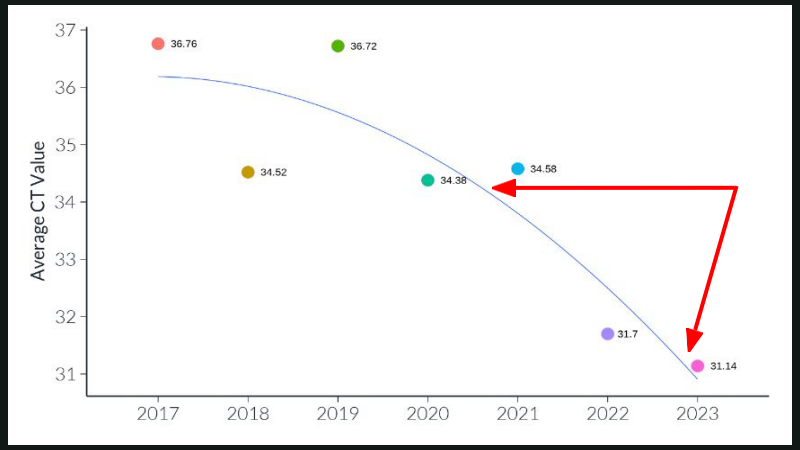

The relative change in CT values across different tree removal regimes is of a similar magnitude to the relative change in CT values from 2020 to 2023

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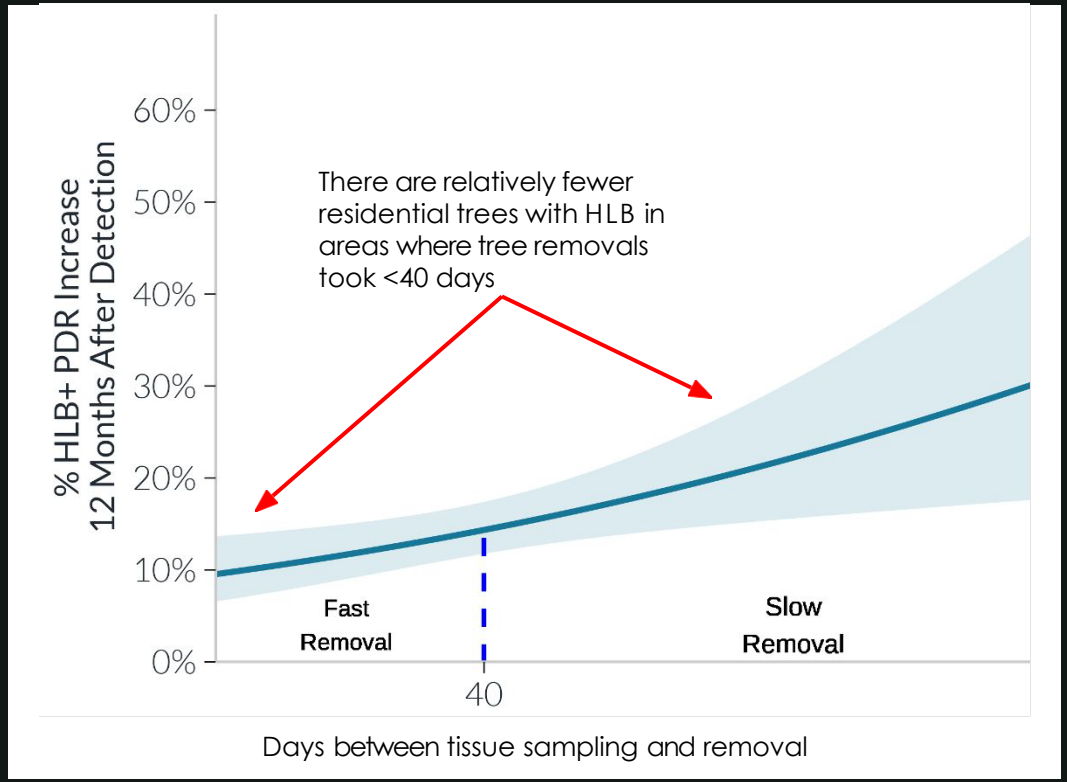
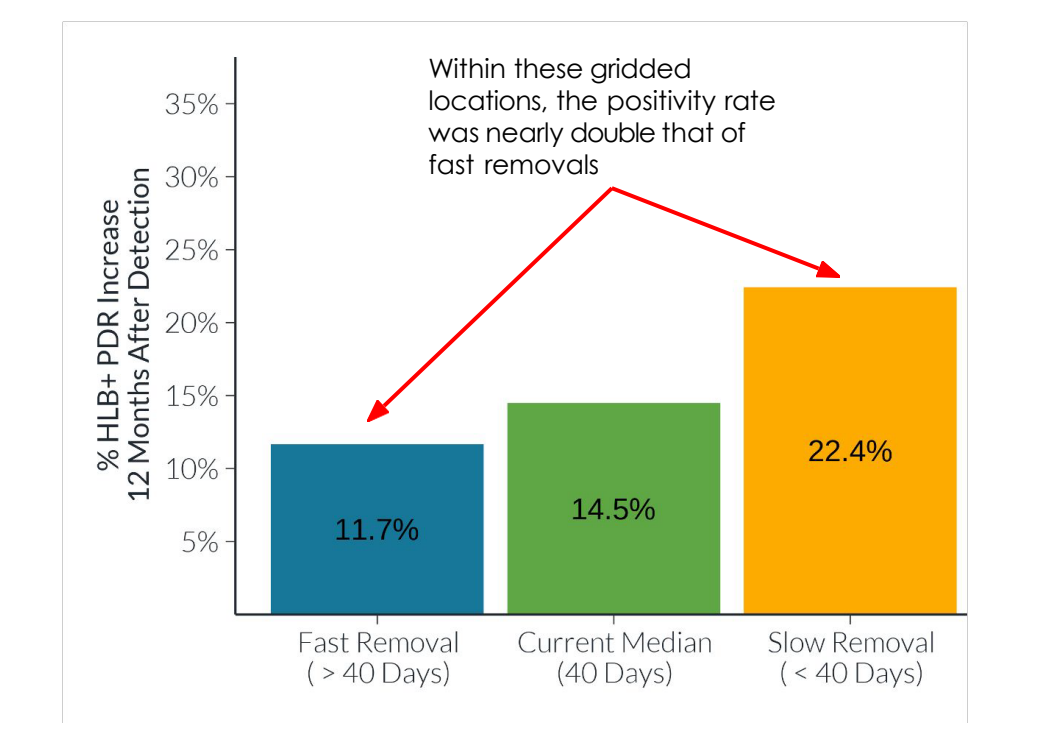
Q2: 12 months later, the positivity rate (% of PDRs with CLas) is significantly lower in fast removal locations



The CLas+ positivity rate in fast removal locations is half that of slow removal, but this effect is only seen within the 1.4 km x 1.4 km gridded locations



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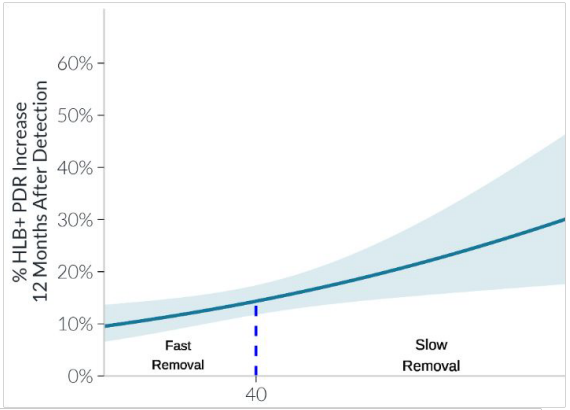
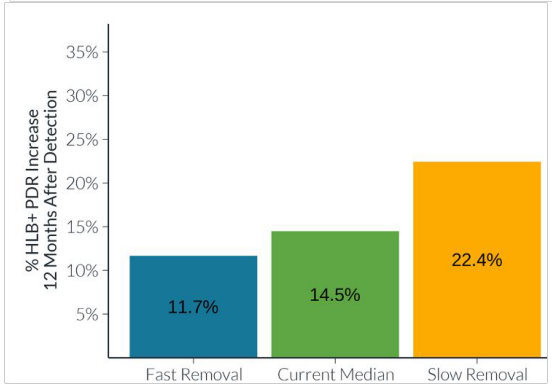
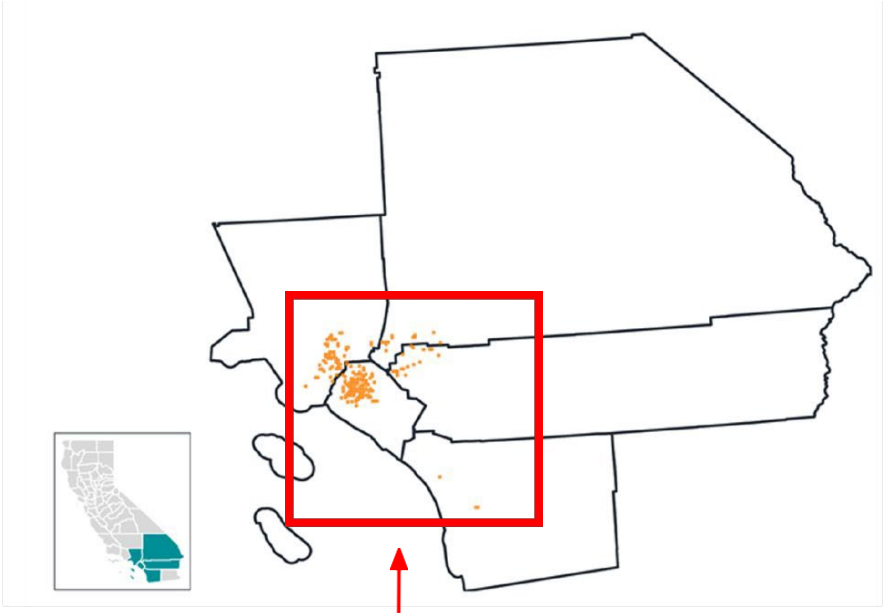




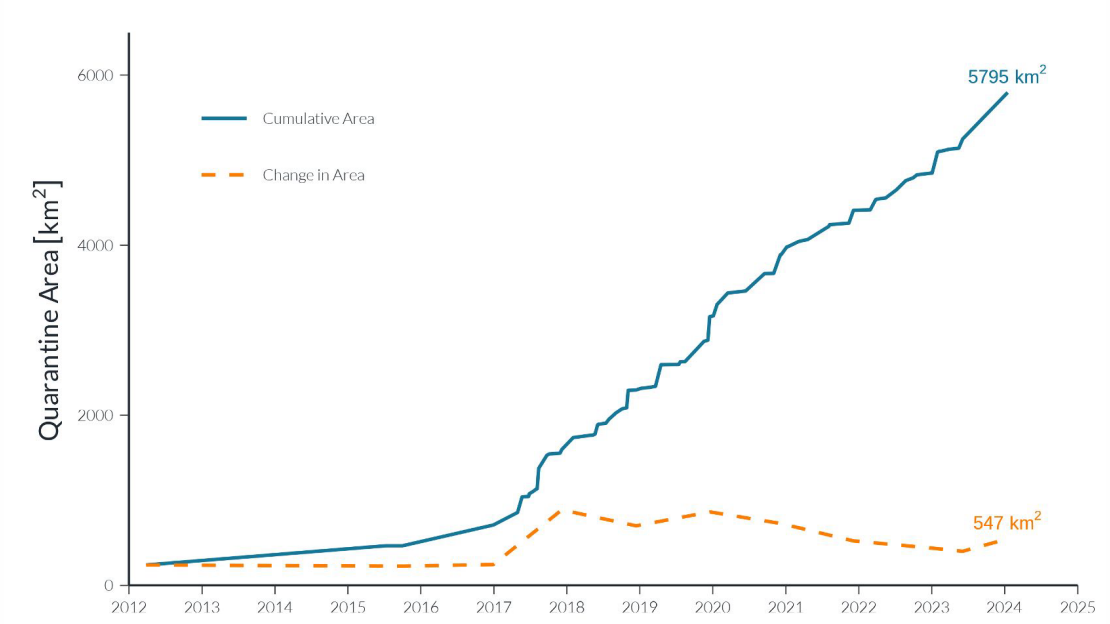


Both results come from a subset of gridded locations where tree removals occurred and then enough subsequent HLB testing took place to calculate proportions

Takeaways

- Fast tree removals look impactful at small scales – there are proportionally fewer infected trees, and those infected trees have higher CT values
- Since there are far more citrus trees than can be possibly be tested, further research should determine if these local impacts scale up or not
- Based on the current results, it is my opinion that the change in CT values and proportion of infected trees is enough to impact the HLB disease reservoir. I encourage the discussion about where tree removals will provide the most value

Future data analysis by DATOC will examine if these location-specific patterns are relevant to the larger HLB management area (QZ), or if other factors are more important for determining the rate of QZ expansion



This analysis shows: QZ area has expanded consistently since 2018 at ~550 kmA2 per year, reaching a cumulative area of 5795 kmA2 in January of 2024

EcoData

Actual HLB Situation estimation in Southern CA

Weiqi Luo

Neil McRoberts

Support: CRB #5300-100

Background

The HLB situation is Southern CA is still much better than in other major citrus States in the US. However, there is an urgent need to adjust the design of RBS/MPS survey to account for the specific HLB-related challenges faced by citrus growers in different regions.

How many HLB+ trees in the landscape?

- **Disease surveys**, like snapshots, show part of the disease situation, but may miss the bigger story.

- **Mathematical modeling** can go beyond the limited view of surveys, painting the full picture of the disease landscape.

- Having a **comprehensive understanding of the actual HLB situation** will enable more effective surveillance design and support cost-efficient management decisions

Survey

\+

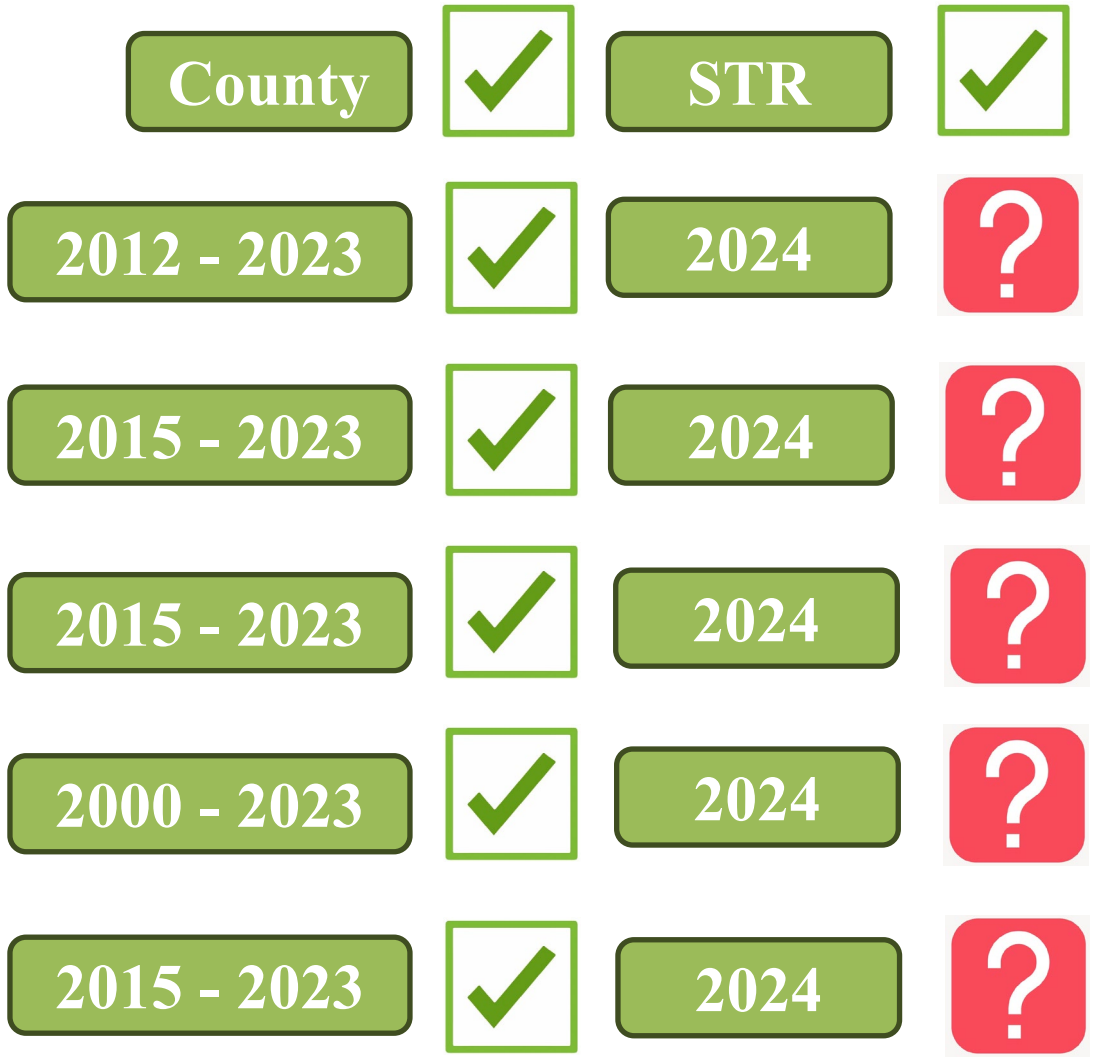
Modeling

What we know so far for HLB epidemic in Southern CA

Questions we can answer

- **Residential and commercial citrus host map**
  i.e. How many dooryard citrus trees?
- **HLB (RBS or MPS) Survey coverage**
  i.e. Any areas we haven't surveyed in the past 5 years?
- **Sampled HLB prevalence and positivity rate**
  i.e. Any locations with higher trend of HLB detection?
- **Impact of different risk factors on HLB spread**
  i.e. Relationship with ACP density, citrus road, packinghouse, etc.?
- **Climate suitability for ACP development**
  i.e. Any adverse climate events (freezing winter) for ACP survival?
- **Actual HLB situation (min & max)**
  i.e. How many HLB infected trees out there?

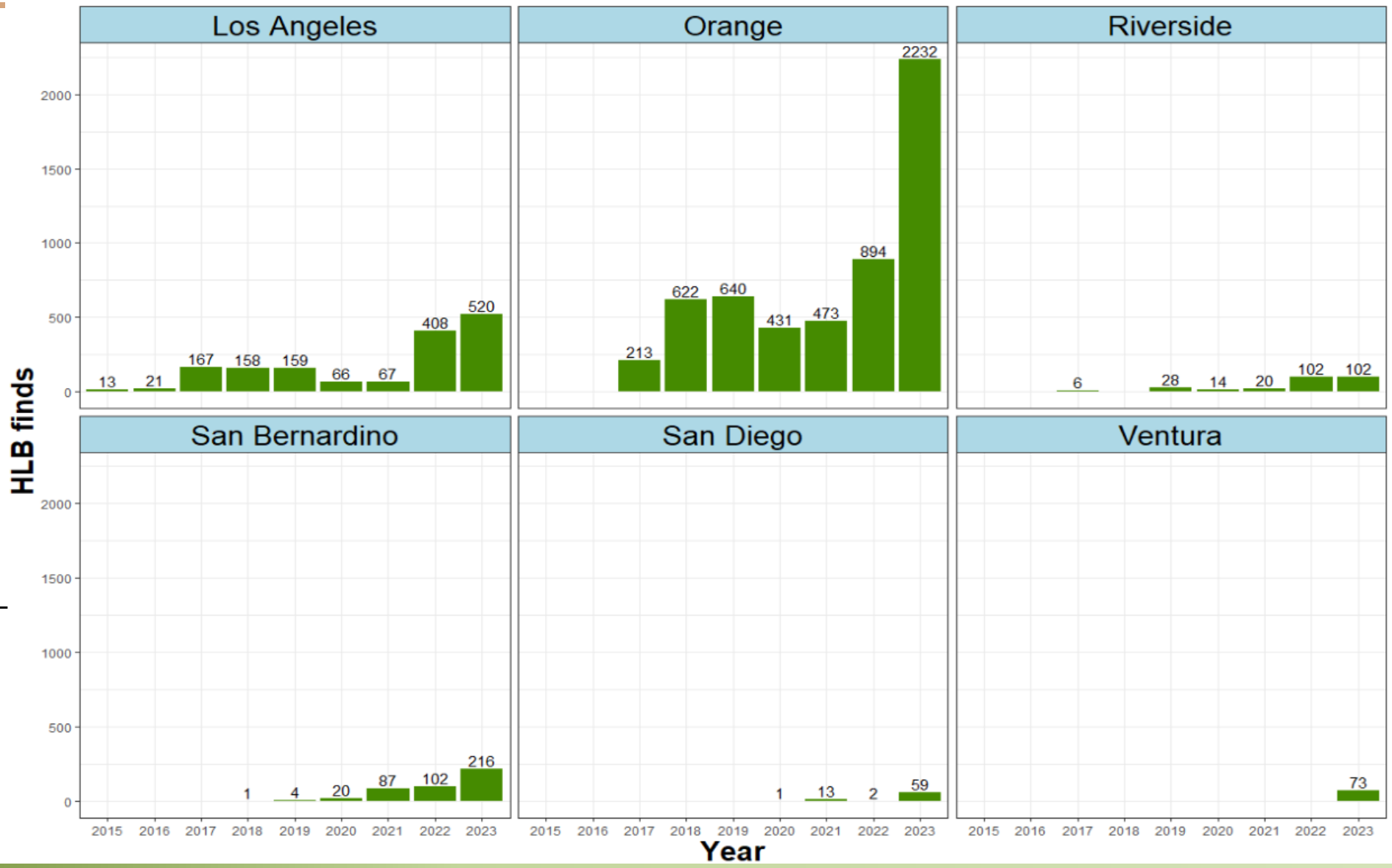
Available outputs



HLB detections in Southern CA, 2015 - 2023

Fixed scale for cross comparison between counties

All panels have the same Y axis



Totally, 7,936 CLas+ trees or ACP detected by the end of 2023

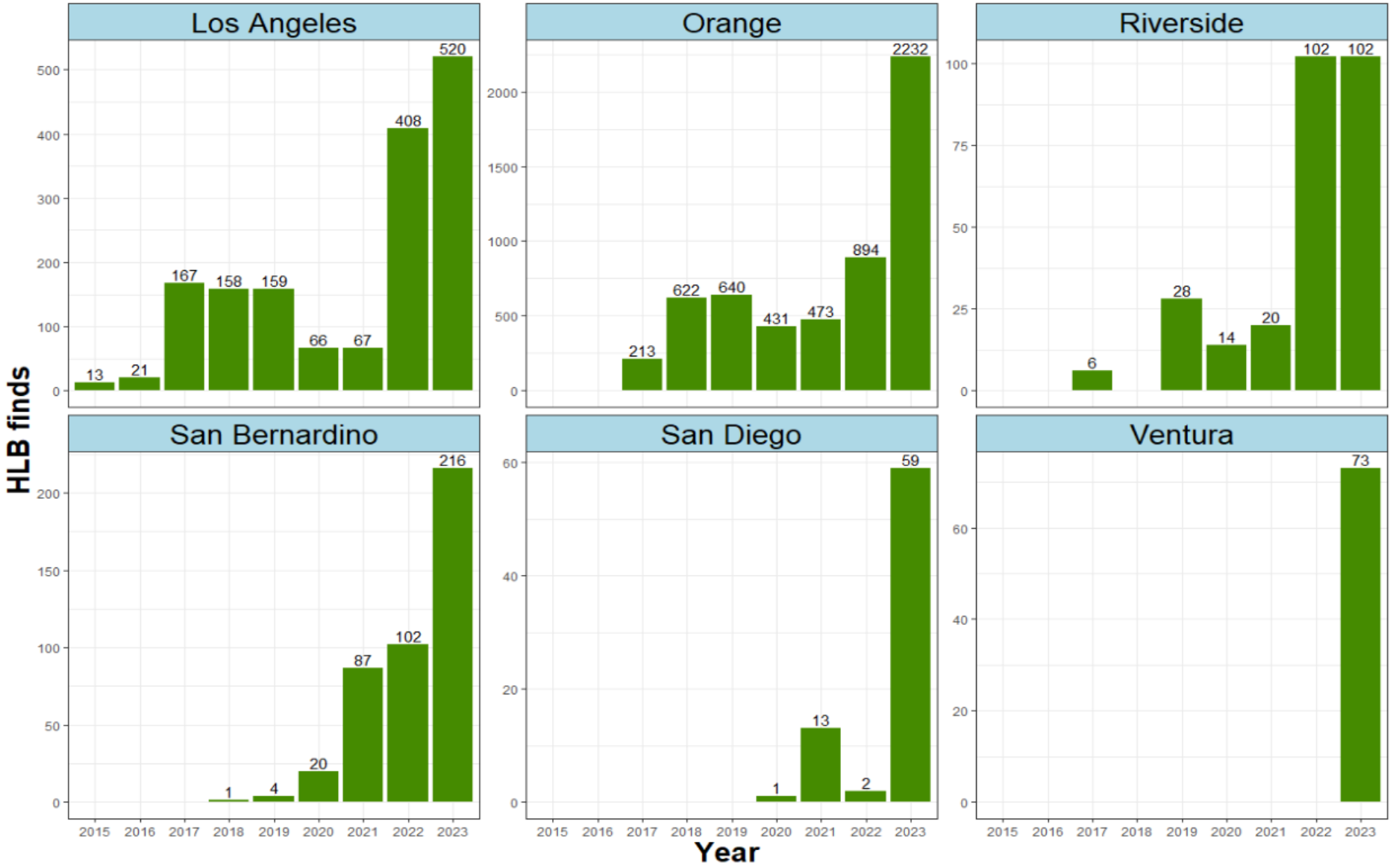
HLB detections in Southern CA, 2015 - 2023

Dynamic scale for temporal trend identification

Each panel has its own Y axis

Exponential increase phase?

What is the actual HLB situation?



HLB finds and sampling effort (by area)

Sampled STRs confirmed with HLB finds

County	2015	2016	2017	2018	2019	2020	2021	2022	2023
Los Angeles	2	5	12	21	25	14	12	58	54
Orange	0	0	19	35	50	46	36	44	104
Riverside	0	0	2	0	2	6	5	12	14
San Bernardino	0	0	0	1	4	7	8	5	11
San Diego	0	0	0	0	0	1	1	2	3
Ventura	0	0	0	0	0	0	0	0	2

STR = 1 sq mile grid

Total STRs sampled by county and year

County	2015	2016	2017	2018	2019	2020	2021	2022	2023
Los Angeles	905	1,021	615	842	656	603	642	487	185
Orange	318	218	166	288	284	333	280	231	195
Riverside	681	615	363	316	344	427	437	337	142
San Bernardino	266	248	153	129	178	214	193	179	62
San Diego	839	608	454	571	523	619	713	673	374
Ventura	210	252	240	220	190	268	227	227	145

HLB finds and sampling effort (by locations)

Number of confirmed HLB finds by county and year

County	2015	2016	2017	2018	2019	2020	2021	2022	2023
Los Angeles	13	21	167	158	159	66	67	408	520
Orange	0	0	213	622	640	431	473	894	2,232
Riverside	0	0	6	0	28	14	20	102	102
San Bernardino	0	0	0	1	4	20	87	102	216
San Diego	0	0	0	0	0	1	13	2	59
Ventura	0	0	0	0	0	0	0	0	73

Total samples by county and year

County	2015	2016	2017	2018	2019	2020	2021	2022	2023
Los Angeles	42,873	72,861	44,390	51,458	38,226	18,183	21,133	34,454	15,274
Orange	12,380	8,608	30,767	51,687	31,647	30,418	15,000	14,167	18,839
Riverside	23,660	16,959	15,816	11,468	12,010	12,530	13,027	12,317	5,291
San Bernardino	10,719	10,734	6,914	8,146	7,335	11,586	10,496	9,917	9,678
San Diego	16,221	13,176	15,954	20,218	16,757	16,644	18,305	20,623	7,181
Ventura	2,064	4,153	2,986	2,121	2,156	4,311	2,890	3,264	1,487

Methodology on HLB prevalence estimation

Method: We use the binomial probability law to estimate HLB prevalence with consideration of sampling effort and spatial pattern *(assuming no false negative for sampling).*

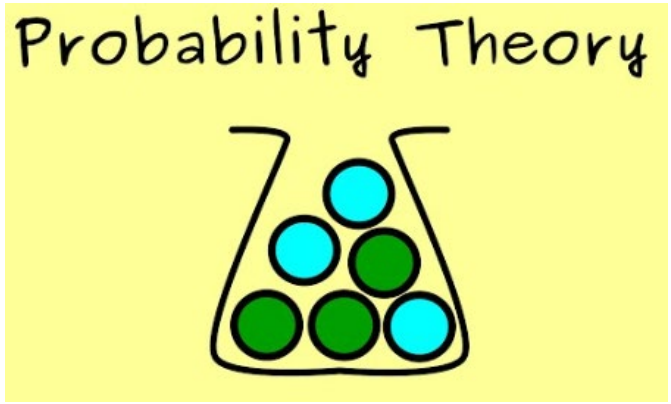
$$P(x|f,p) = (1-f)0^x + f\binom{n}{x}p_{\text{pool}}^x(1-p_{\text{pool}})^{n-x}$$

$$= (1-f)0^x + f\binom{n}{x}(1-q^m)^x q^{m(n-x)}$$

HLB Spatial Pattern

Sampling Effort

Distance to nearby HLB finds



Population: Mix of healthy and HLB+ trees in the landscape
Survey: Sampling a proportion of trees in different areas following RBS/MPS design

Determine **actual HLB prevalence and distribution** for optimized management

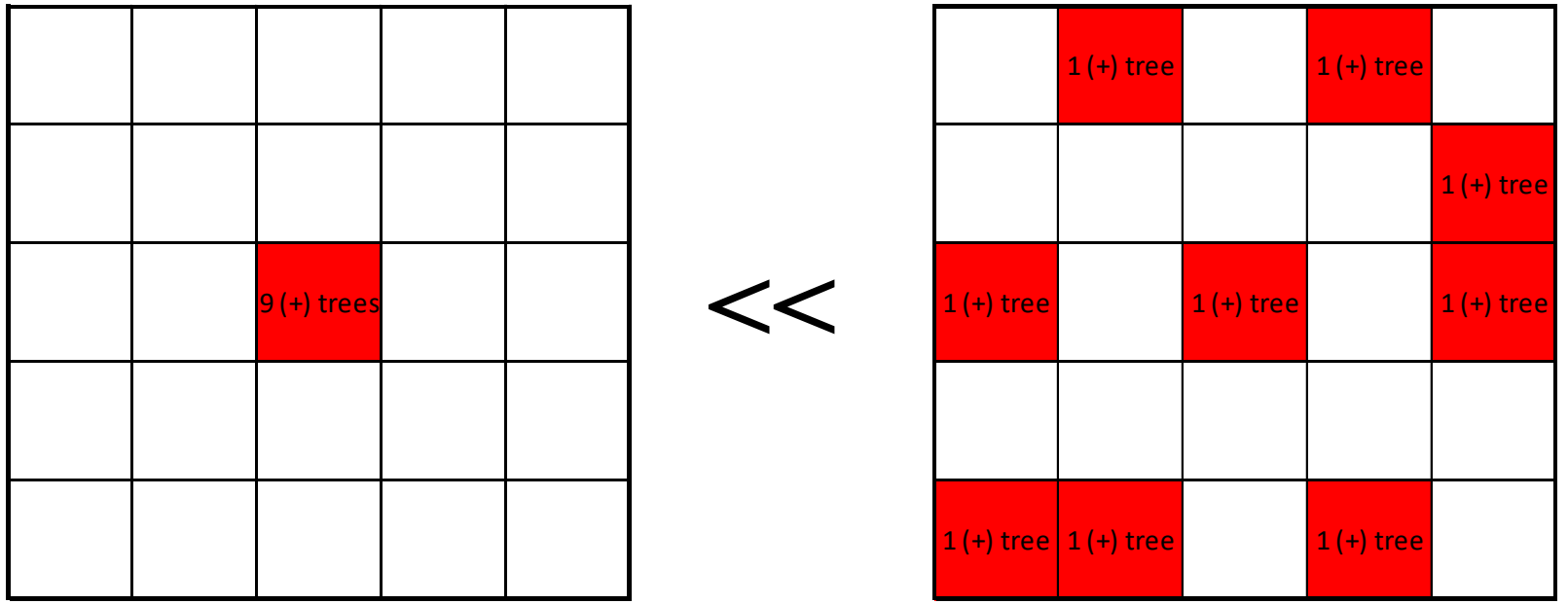
HLB counts ≠ HLB situation

HLB Spatial Pattern

Understanding the spatial pattern and distribution of positive locations makes a considerable difference in understanding the severity of infection in an area.

Looking at the two landscapes below, both contain 9 positive trees found out of 100 samples taken from the entire area, but *which is the more severe infection scenario?*

HLB detection pattern matters!!!



HLB counts ≠ HLB situation

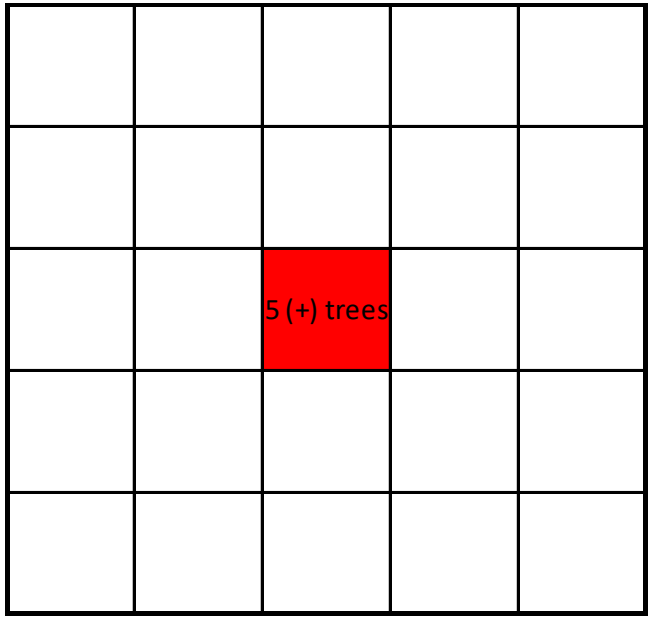
Sampling Effort

Understanding the extent of sampling efforts when looking at positive locations makes a considerable difference in understanding the prevalence and severity of infection in an area.

In both the landscapes below, 5 positive trees were detected, but *which is the more severe infection scenario?*

Negative sample matters!!!

5 (+) trees out of 1000 samples taken



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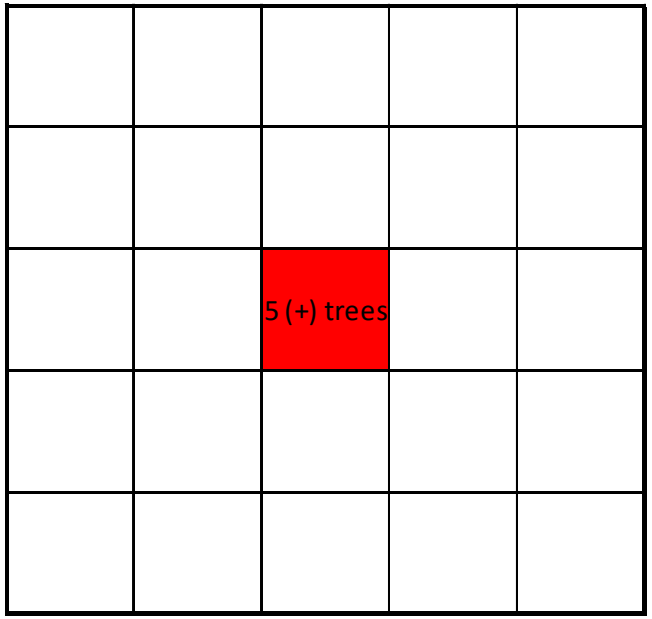
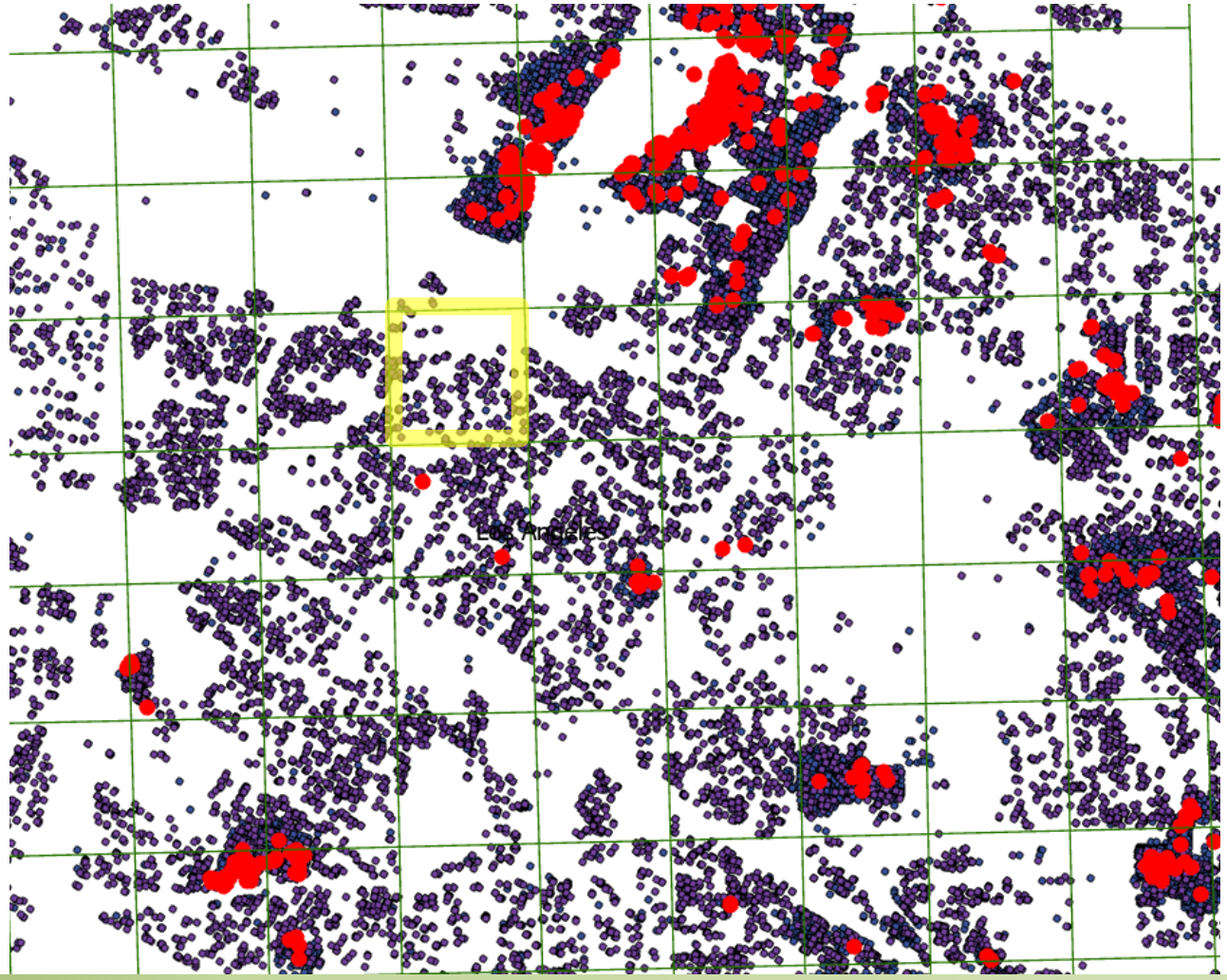
5 (+) trees out of 10 samples taken



HLB counts ≠ HLB situation

Distance to nearby HLB finds

Location surrounded with many HLB finds will have higher HLB prevalence



Any hidden HLB+ trees inside the yellow box?

Red dot: HLB finds

Black dot: sample locations

HLB counts ≠ HLB situation

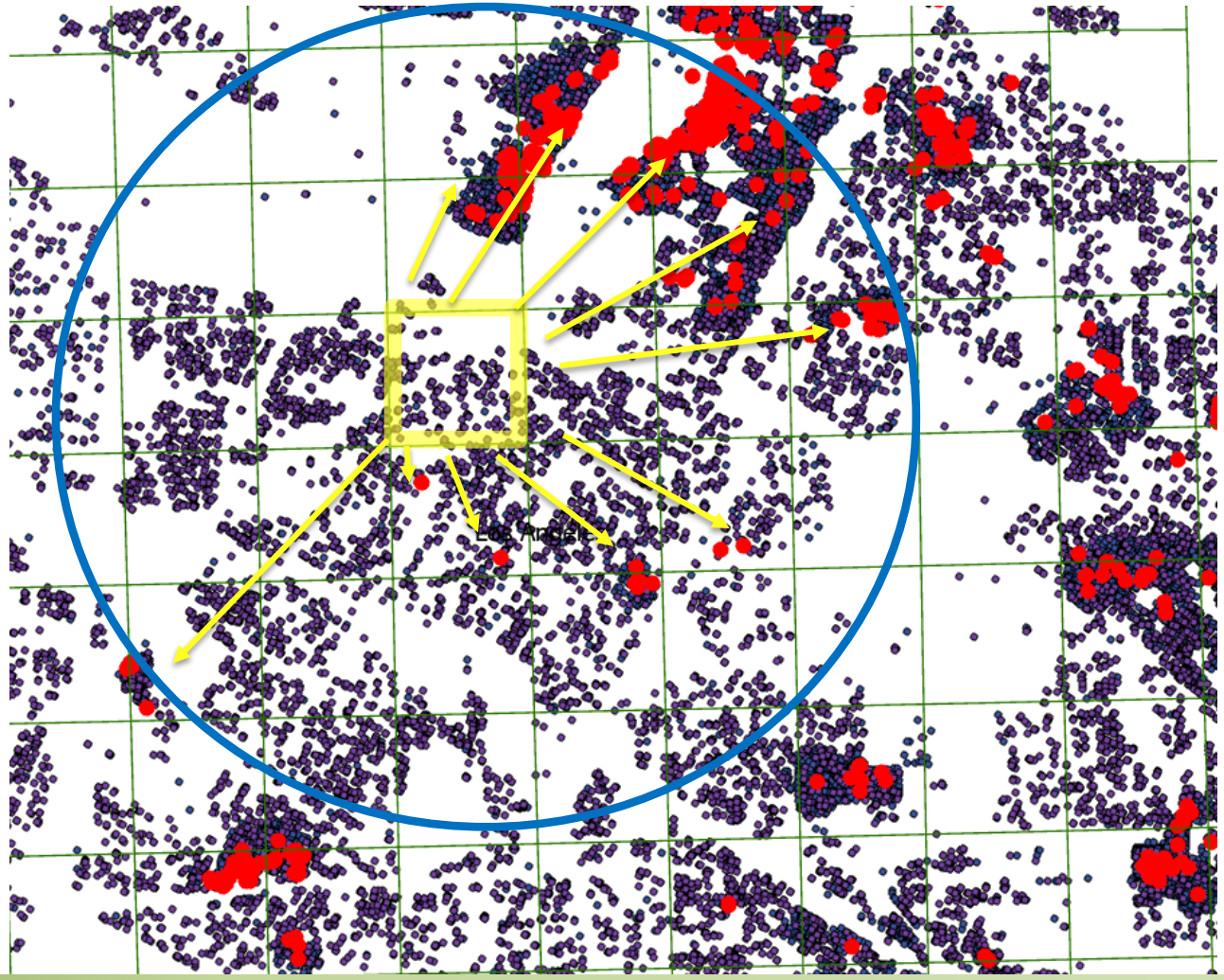
Distance to nearby HLB finds

HLB neighbor matters!!!
How far of Neighbor HLB+ trees?
When are they detected?

Any hidden HLB+ trees inside the yellow box?

5km searching radius (blue circle) for neighbor HLB+ trees.

Location surrounded with many HLB finds will have higher HLB prevalence



Red dot: HLB finds

Black dot: sample locations

Estimated HLB prevalence (minimum and maximum)

Estimated Minimum HLB Prevalence (assuming no spread beyond confirmed HLB+ STRs)

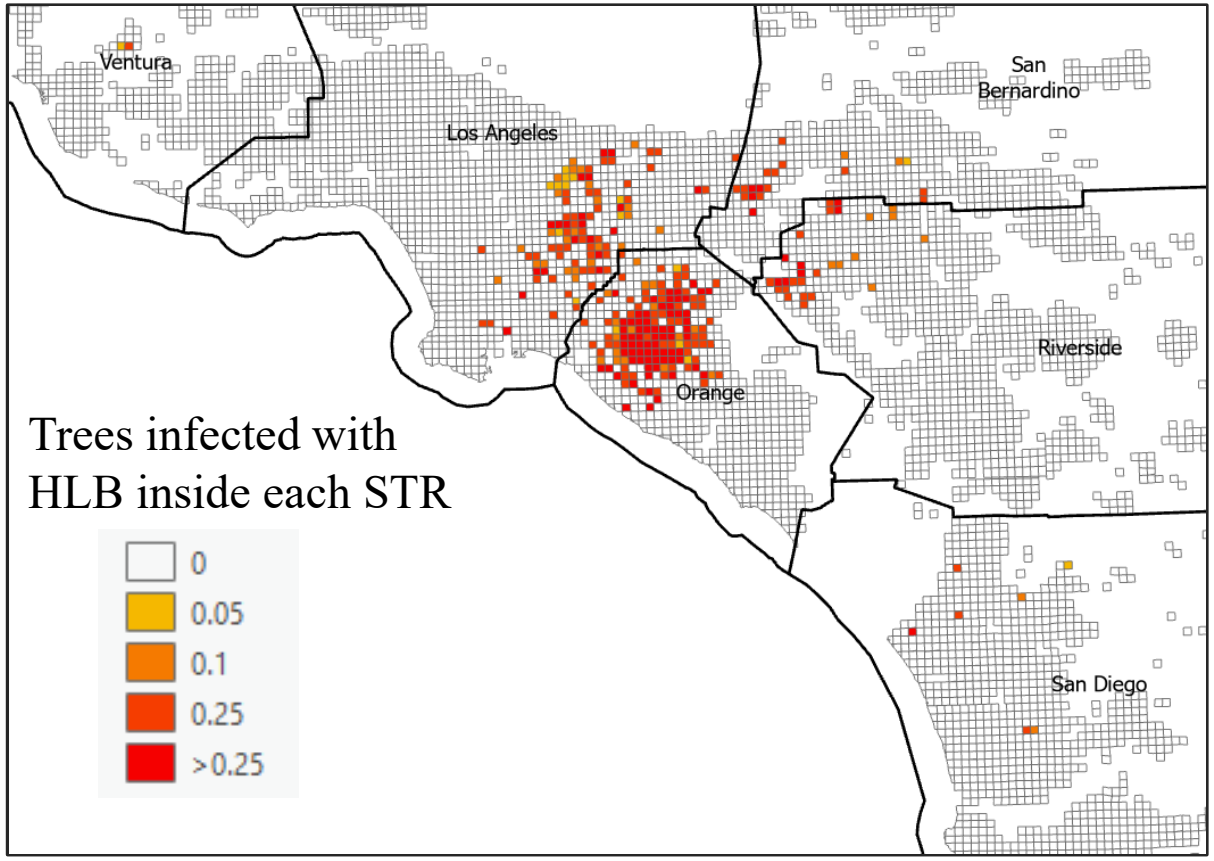
County	2015	2016	2017	2018	2019	2020	2021	2022	2023
Los Angeles	0.1%	0.3%	0.8%	1.5%	2.3%	2.9%	3.0%	4.9%	5.7%
Orange	0.0%	0.0%	3.1%	6.9%	11.0%	13.8%	15.3%	17.8%	24.7%
Riverside	0.0%	0.0%	0.2%	0.2%	0.2%	0.6%	0.7%	1.6%	2.2%
San Bernardino	0.0%	0.0%	0.0%	0.1%	0.4%	0.7%	1.0%	1.2%	1.5%
San Diego	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.3%	0.6%
Ventura	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%

Estimated Maximum HLB Prevalence (assuming up to 5km spread from confirmed HLB+ locations)

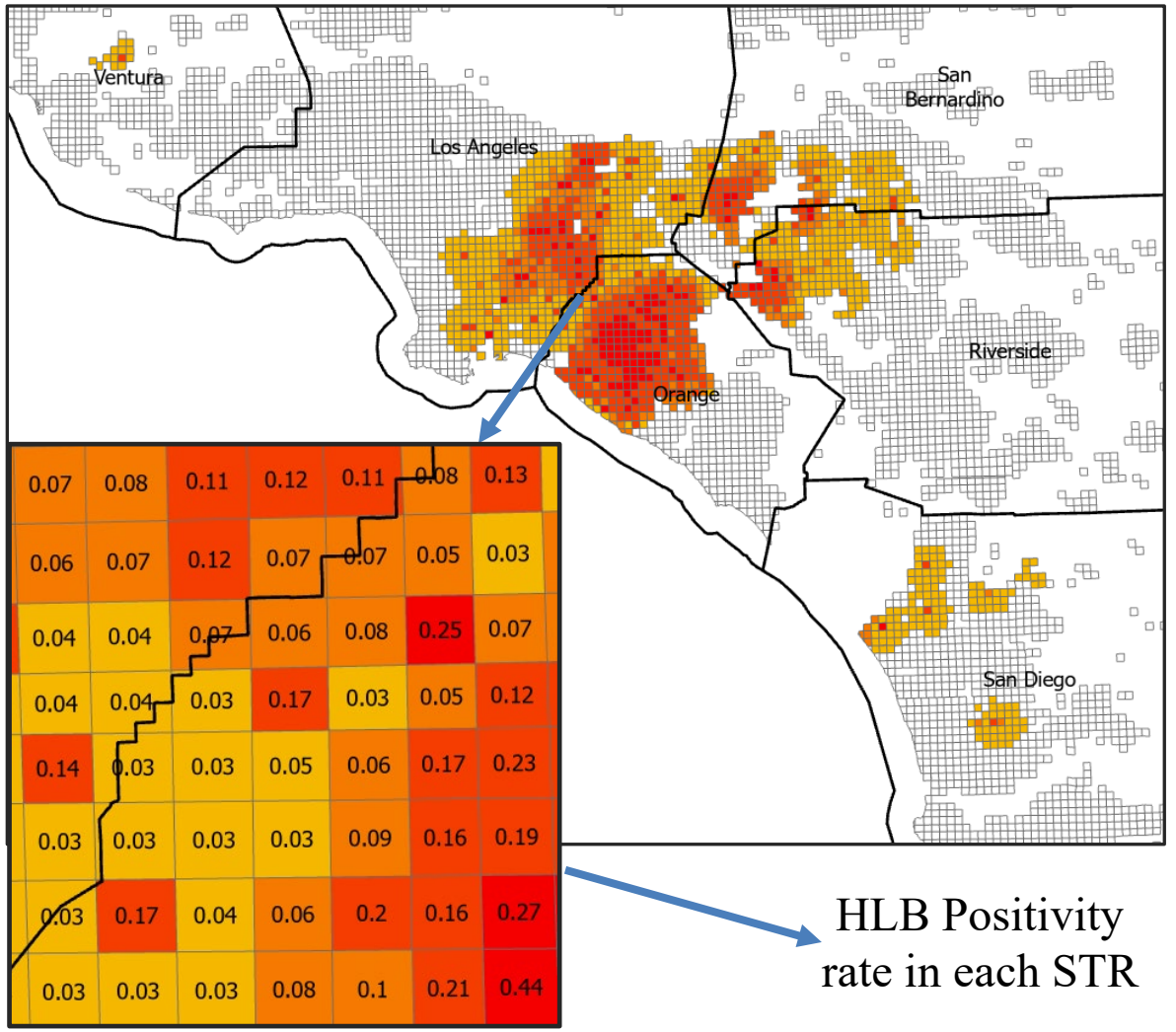
County	2015	2016	2017	2018	2019	2020	2021	2022	2023
Los Angeles	2.0%	5.8%	11.0%	13.1%	17.7%	21.9%	23.3%	28.9%	30.6%
Orange	0.0%	1.3%	25.7%	41.3%	47.4%	53.6%	55.1%	58.6%	61.2%
Riverside	0.0%	0.0%	2.1%	2.1%	3.4%	10.7%	13.9%	17.3%	17.4%
San Bernardino	0.0%	0.0%	0.6%	3.1%	7.9%	12.7%	13.3%	14.7%	15.3%
San Diego	0.0%	0.0%	0.0%	0.0%	0.0%	2.2%	4.5%	7.6%	12.0%
Ventura	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.2%

Estimated HLB situation & distribution (2023)

Minimum HLB Prevalence



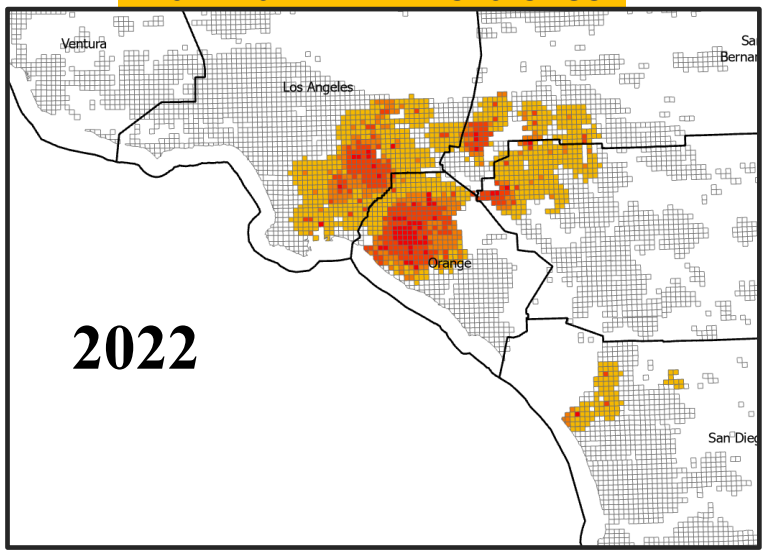
Maximum HLB Prevalence

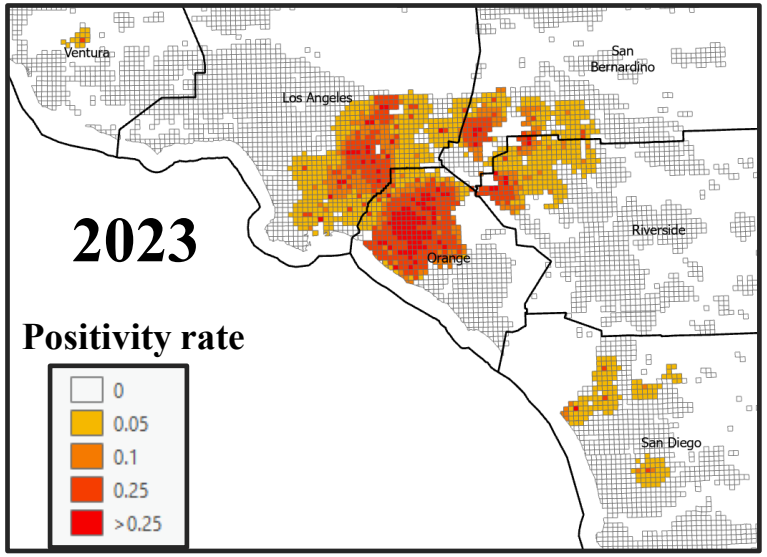


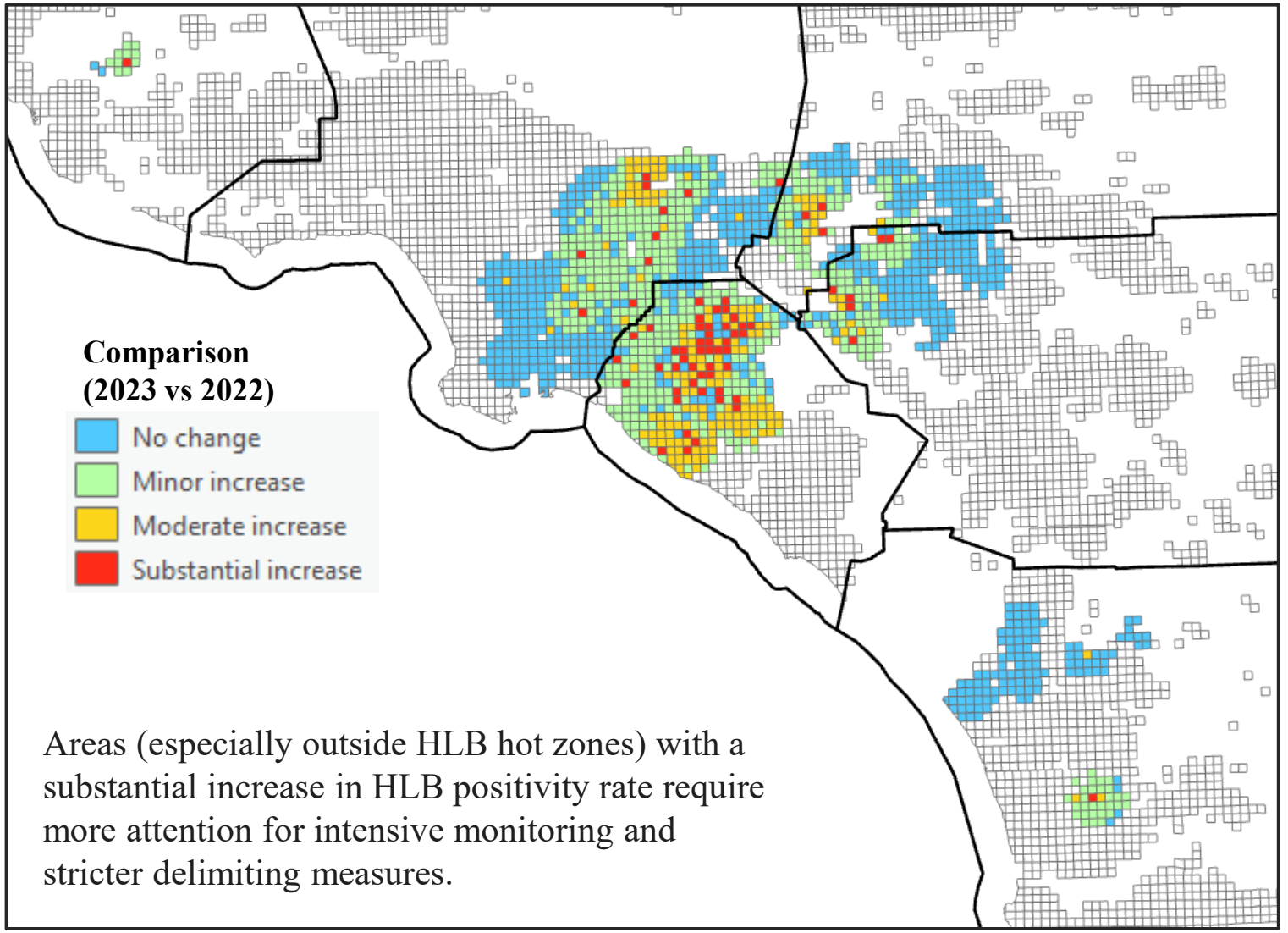
While many STRs are predicted to contain HLB+ trees, the overall HLB positivity rate remains low in most areas.

Temporal comparison for HLB situation (2023 vs 2022)

Maximum HLB Prevalence





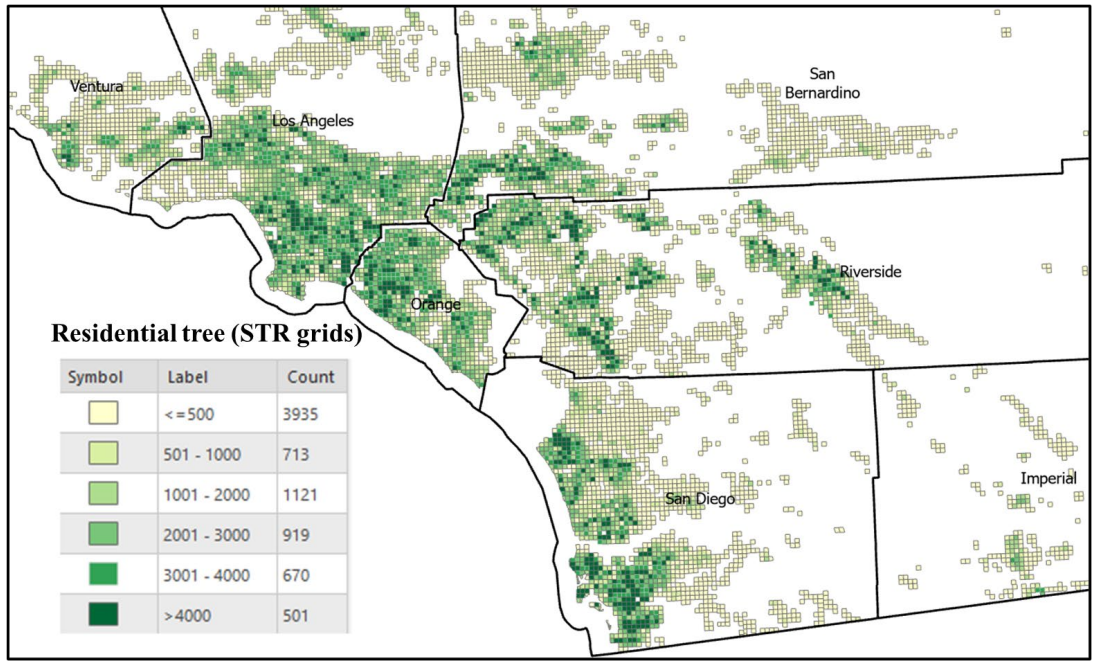


Areas (especially outside HLB hot zones) with a substantial increase in HLB positivity rate require more attention for intensive monitoring and stricter delimiting measures.

How many undetected HLB+ trees in each county?

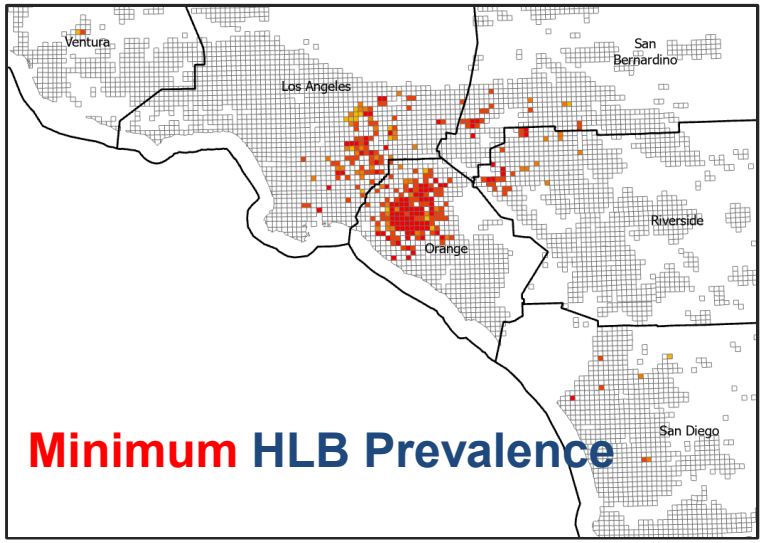
Total dooryard citrus trees in each county

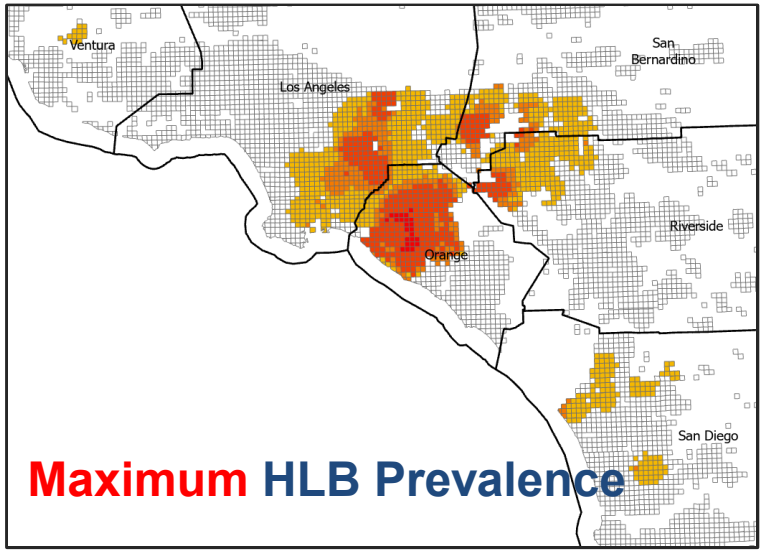
LA	Orange	Riverside	San Bernadino	San Diego	Ventura
1,910,534	572,693	1,040,188	801,429	1,407,285	262,893



Residential citrus density

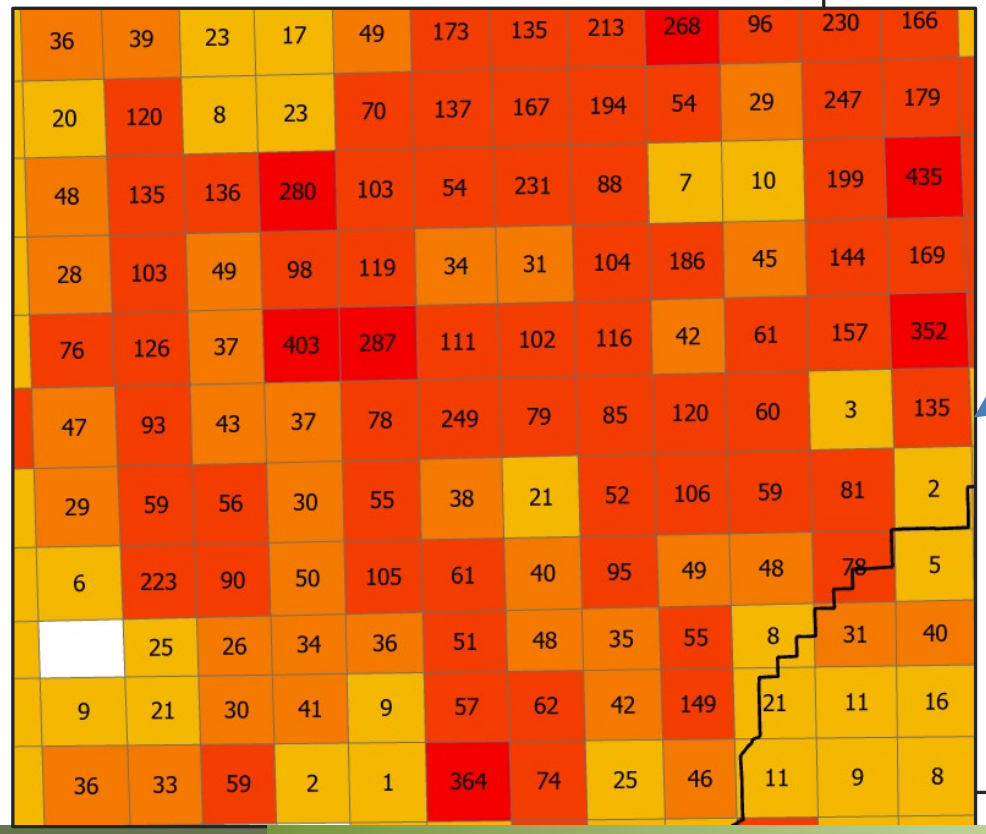
×

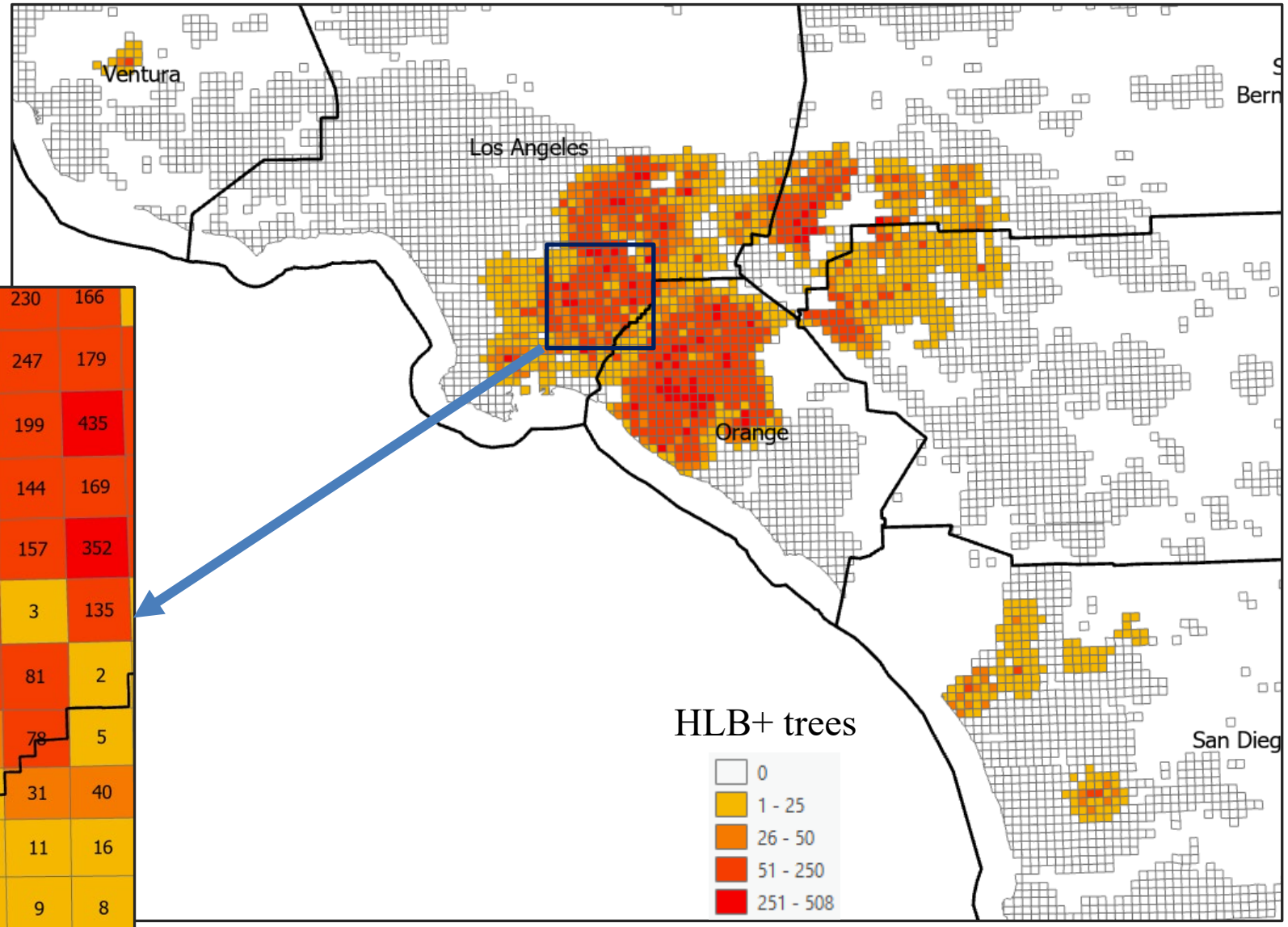




How many undetected HLB+ trees in each county?

HLB+ trees in each STR (Maximum Prevalence) 2023





How many hidden HLB+ trees out there

Estimated Minimum hidden HLB+ trees in the landscape

County	2015	2016	2017	2018	2019	2020	2021	2022	2023	% of total residential citrus tree (2023)
Los Angeles	154	245	2,105	2,757	4,112	5,291	5,543	11,141	15,005	0.79%
Orange	0	0	3,067	4,338	8,372	10,306	11,982	15,139	24,157	4.22%
Riverside	0	0	74	67	342	645	630	1,566	2,210	0.21%
San Bernardino	0	0	0	50	506	820	1,468	2,019	2,824	0.35%
San Diego	0	0	0	0	0	85	251	289	442	0.03%
Ventura	0	0	0	0	0	0	0	0	87	0.03%

Estimated Maximum hidden HLB+ trees in the landscape

County	2015	2016	2017	2018	2019	2020	2021	2022	2023	
Los Angeles	1,326	1,626	6,796	8,063	11,502	13,341	14,219	23,068	31,068	1.63%
Orange	0	36	6,178	10,656	15,656	17,534	20,039	24,706	36,721	6.41%
Riverside	0	0	230	193	845	1,704	1,904	3,682	5,011	0.48%
San Bernardino	0	0	46	387	1,843	3,562	6,589	8,029	10,571	1.32%
San Diego	0	0	0	0	0	169	1,188	1,131	1,710	0.12%
Ventura	0	0	0	0	0	0	0	0	118	0.04%

Conclusion

- Our established methodology can provide reasonably accurate estimates for the actual HLB situation.
- Riverside, San Bernardino, San Diego, and Ventura counties are still in the early HLB phase, avoiding exponential growth yet.
- HLB detections in Orange County exhibit greater clustering compared to other counties. At least 25% of areas have confirmed HLB infections, and the disease may have already spread to 60% of the area.

Benefits:

- **Strategic resource allocation**: Knowing the actual HLB situation allows us to improve survey design, efficiently assign manpower to areas with the greatest need.
- **Proactive measures**: Evaluate the performance of proactive actions (e.g. delimiting responses) in preventing exponential HLB growth in these areas.
- **Cost-effective management**: Measure the impact of knowing the HLB situation (Best & Worst Cases) on decision-making, leading to improved detection rates and resource savings in HLB management.