

Manipulation of release conditions improves establishment of the wasp *Tetramesa romana* for biological control of arundo in northern California

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Biological control agent against arundo:

Shoot tip-galling wasp, *Tetramesa romana* (Hymenoptera: Eurytomidae)



- Widespread in Mediterranean Europe (native range of arundo or ancient introduced).
- Adventive (released accidentally at unknown point in time) in southern California.
- Females reproduce parthenogenetically; 90% of population is female.
- Larvae develop inside arundo shoot tip in 30-35 days.
- The wasp can develop only on the genus *Arundo*.
- Water deficit (drought) slows down development.

Impact of the wasp *T. romana*-Rio Grande Basin of the U.S. and Mexico



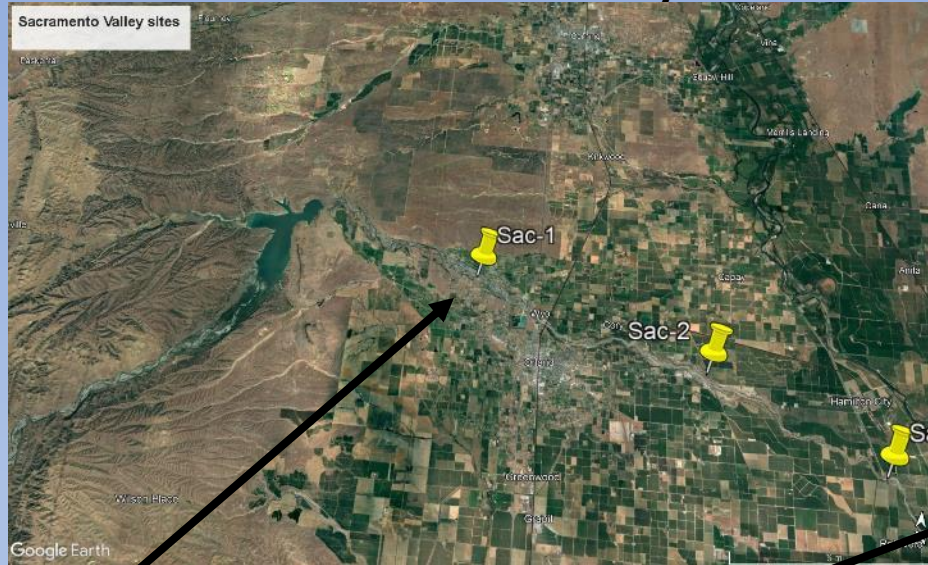
Original releases in the Lower Rio Grande Basin of Texas and Mexico (2009-2012):

- Over 1.2M wasps released, 25 sites.
 - Reduced live biomass by 22% by 2014.
 - Further reduction to total of 44% of pre-biocontrol by 2016.
 - Increased mortality of side shoots.
 - Two to three-fold increase in diversity of other plants.
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- **Released in northern California starting in 2010.**

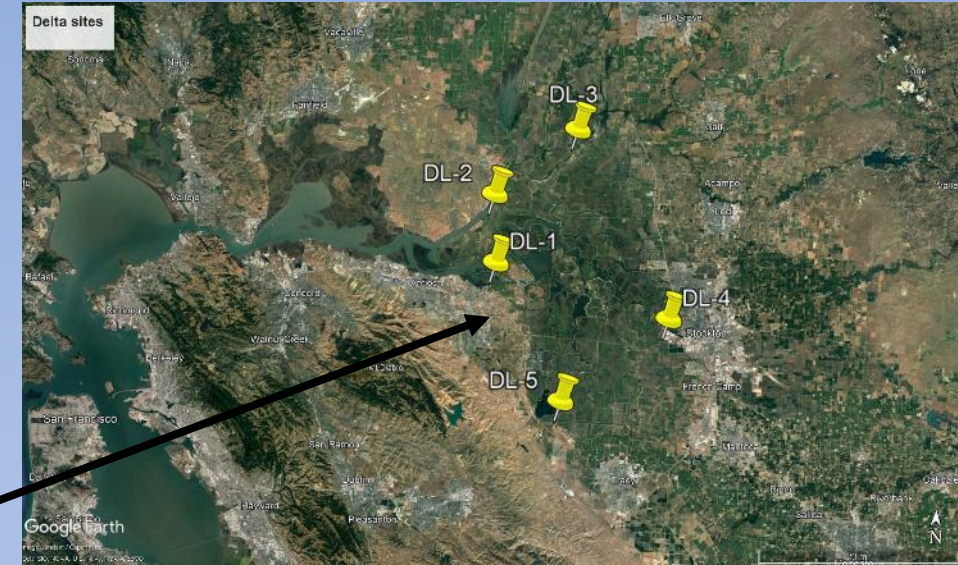
Goolsby et al. 2014, 2016; Moran et al. 2017; Marshall et al. 2018; Goolsby and Moran 2019.

Arundo biological control release sites in California (2017-2020)

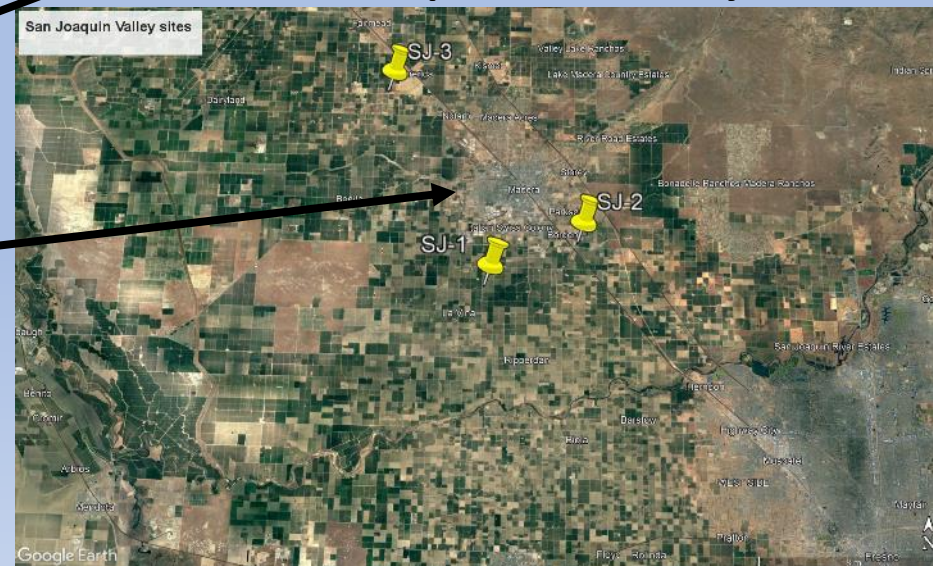
Sacramento River Valley



Sacramento-San Joaquin Delta



San Joaquin River Valley



- Wasps sourced from Texas.
- 11 total sites.
- 5 to 9 plots per site.
- 150 wasps per plot.
- Total of 20,660 wasps.

After one year (2018): Manipulation of host plant influenced local establishment in plots

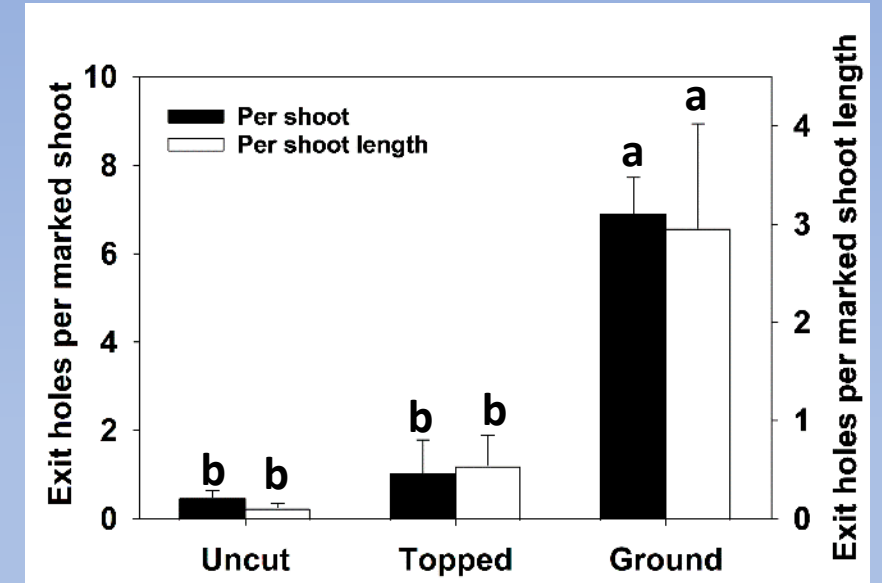
Ground-cut



Topped

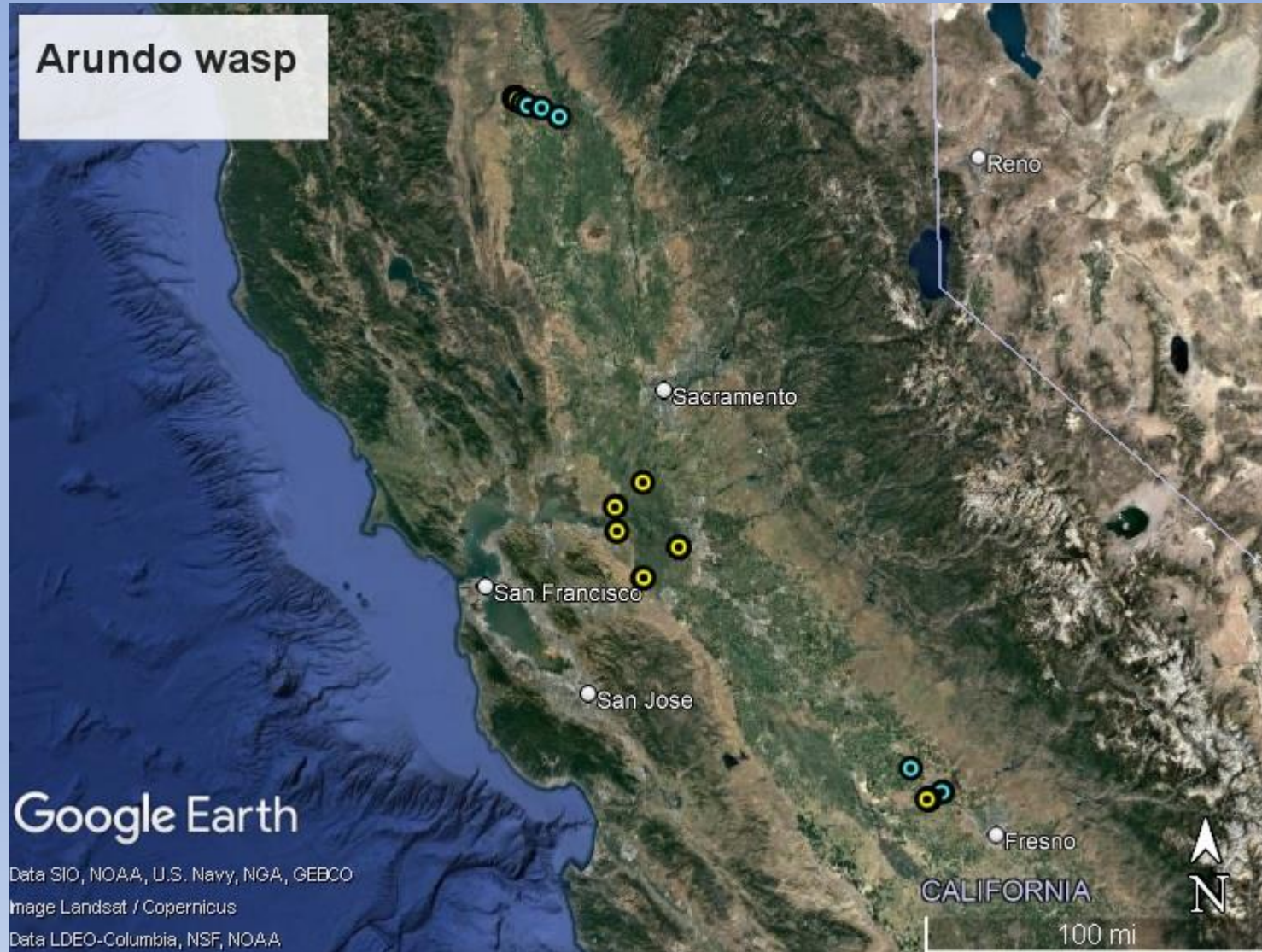


Control plot



- Exit hole density per main shoot length was 26-fold higher in ground-cut than in uncut plots.
- Topped plot exit hole densities were 2 to 4-fold higher but not statistically different from uncut plots.

Arundo wasp establishment survey techniques

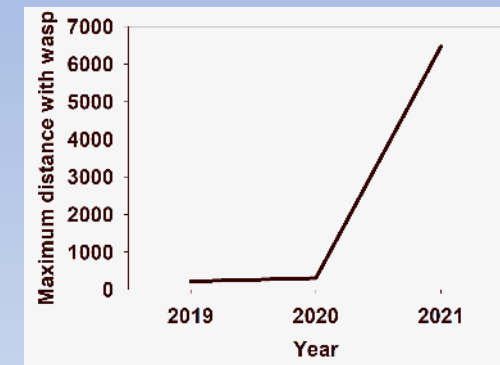
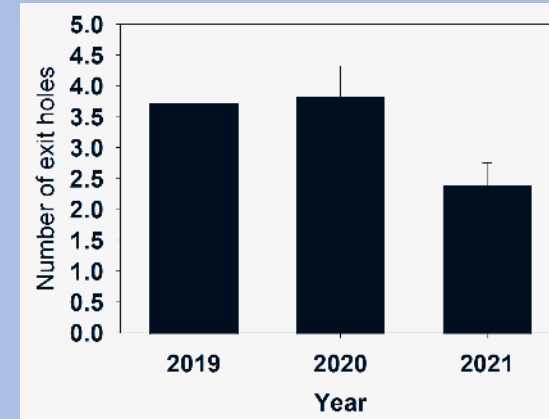
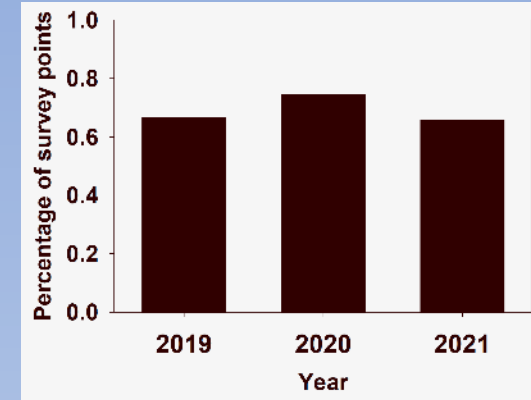


- 2019-2022 survey technique: Two-minute counts of exit holes and galls (without holes).
- 2022 survey technique: Dissection of shoots (At seven well-established sites started in 2017).
- 2023 survey technique: Yellow sticky traps (to capture adult wasps).
- **Multi-year evidence of arundo wasp establishment: 10 of 11 sites.**

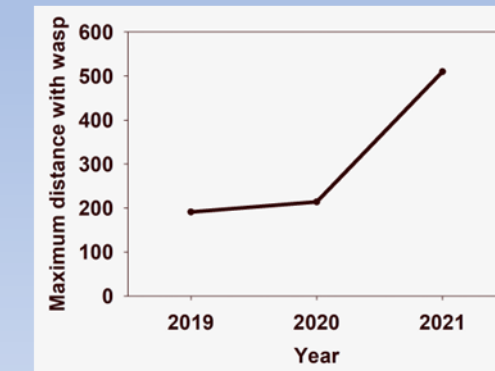
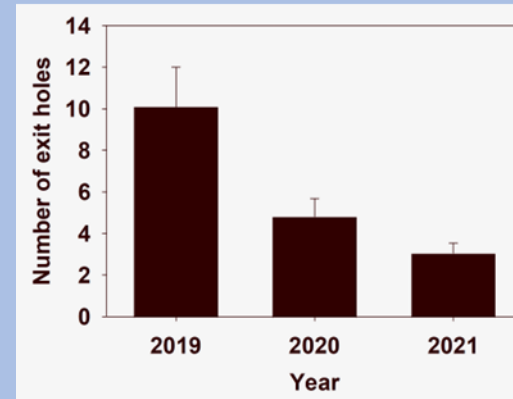
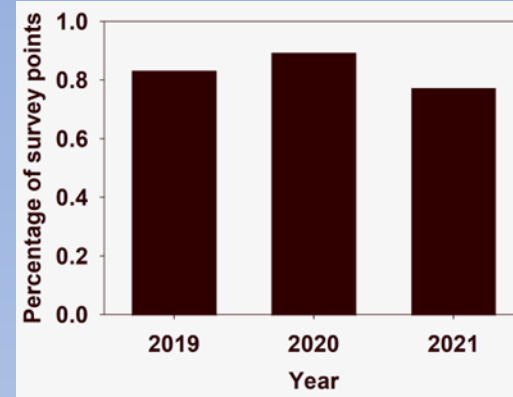
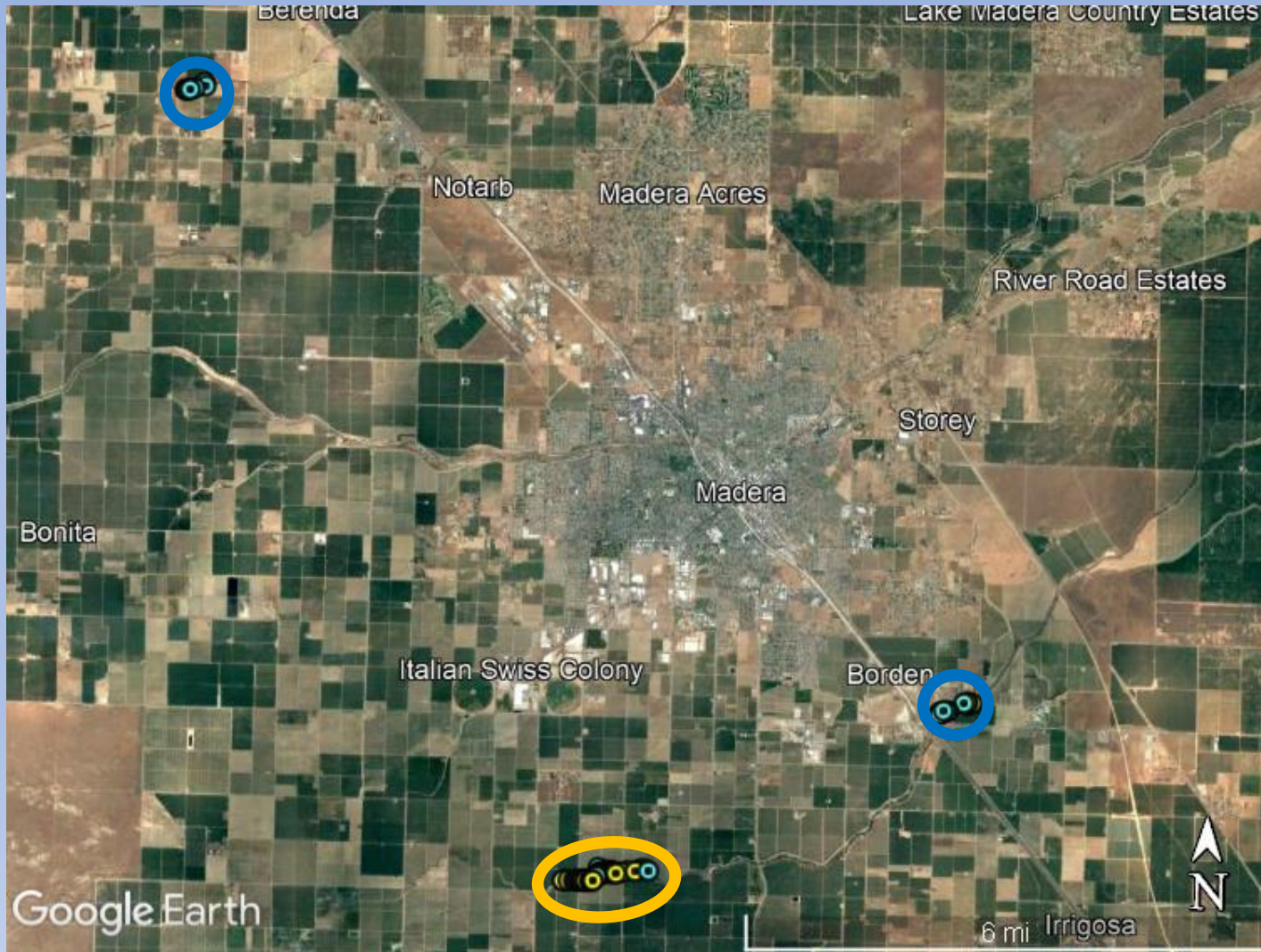
2019-2021 two-minute surveys- arundo wasp established in the northern Sacramento River watershed



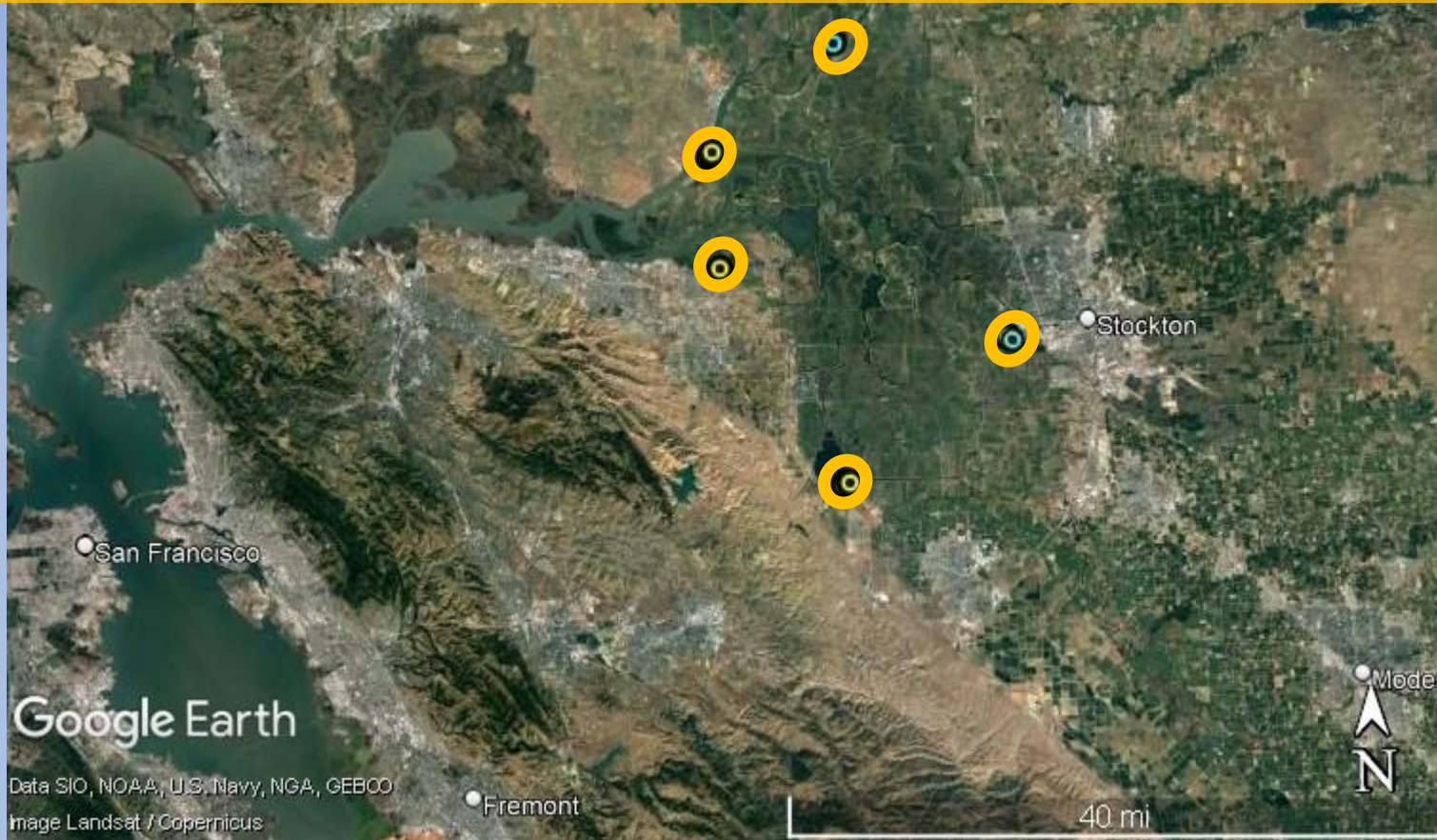
- Over 120 points surveyed each year-2019-2021.
- Over 50% of points had at least one exit hole/ gall.
- Exit hole abundance decreased by 37% in 2021 compared to 2020.
- 6.4 km dispersal observed in 2021.
- The other two other sites downstream-no wasps in 2021.



2019-2021 two-minute surveys-arundo wasp established in the Southern San Joaquin River watershed



2019-2021 two-minute surveys: arundo wasp established in the Sacramento-San Joaquin Delta.



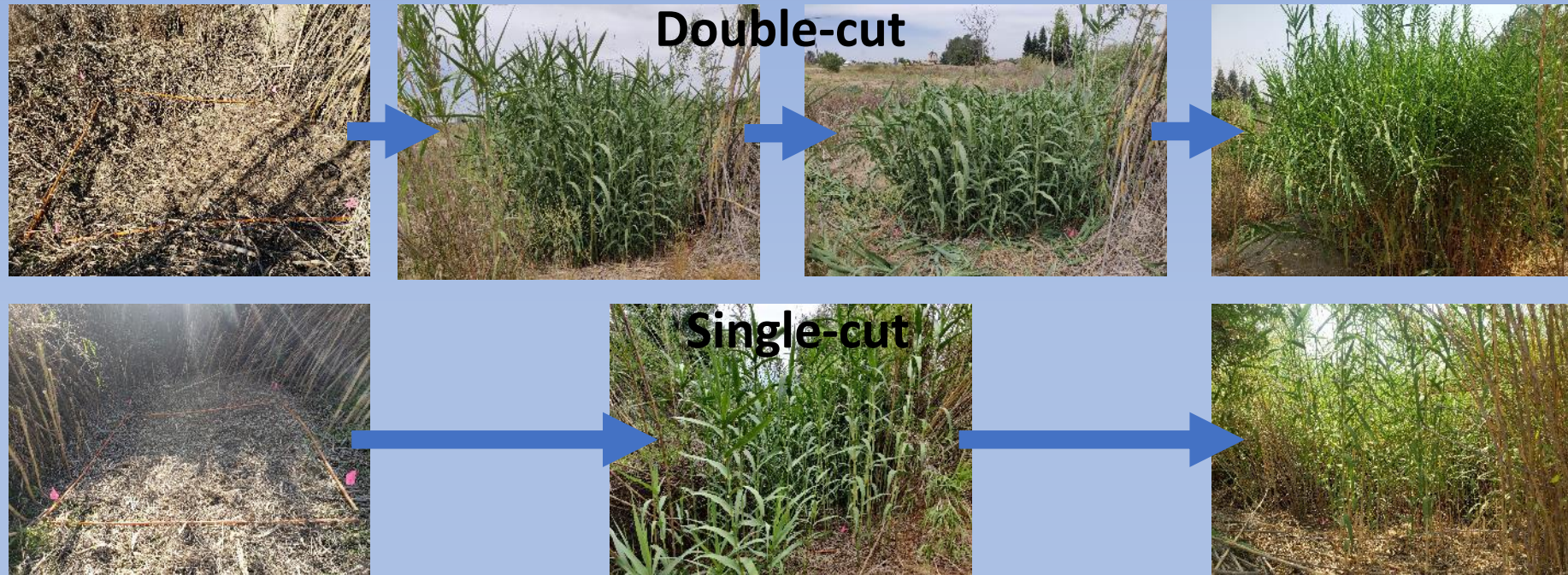
- Establishment of the wasp at all five sites by 2021-avg of 58% of survey points per site.
- Relatively small, isolated arundo populations.
- Two of the five sites sprayed with herbicides, except biocontrol plots.

Results-establishment of arundo wasp in northern California at 10 of 11 sites



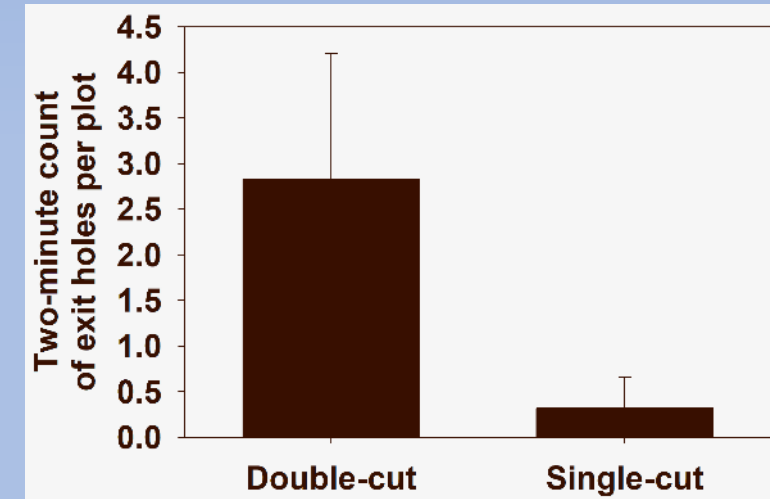
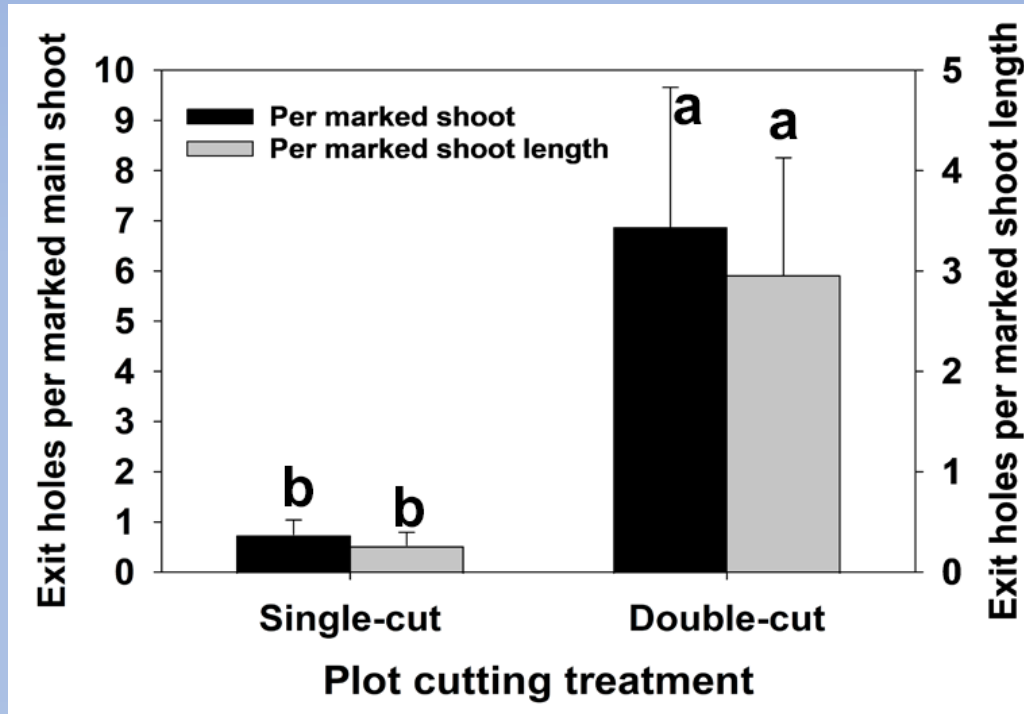
Site	Year of first arundo wasp release	2019: % of survey points with at least one exit hole or gall	2021: % of survey points with at least one exit hole or gall	2022: % of survey points with at least one exit hole or gall	2022-2023: Dissections- Density of exit holes per m main shoot length-2022-2023	2023: Sticky traps, number of wasps captured (over 3 months)	Wasp established?
Sac-1	2017	67%	66%	0	0.15 ± 0.08	1	YES
Sac-2	2017	0	0	ND	ND	0	NO
Sac-3	2017	0	0	ND	In process	6	YES
SJ-1	2017	89%	78%	74%	0.75 ± 0.26	8	YES
SJ-2	2017	13%	17%	27%	In process	2	YES
SJ-3	2017	0	0	13%	In process	7	YES
Delta-1	2017	33%	63%	100%	0.74 ± 0.46	0	YES
Delta-2	2017	25%	88%	89%	0.14 ± 0.12	4	YES
Delta-3	2017	5%	0	50%	0.05 ± 0.02	2	YES
Delta-4	2019	-	30%	63%	1.20 ± 0.10	7	YES
Delta-5	2020	-	54%	33%	0.25 ± 0.10	16	YES

Double-cutting of arundo plots to improve wasp establishment at two sites where establishment from prior released failed.



- Double-cut: Ground cut April 2020, then top regrowth to 1.5 m height June-July 2020.
- Single cut: Ground cut April 2020, regrowth, no subsequent topping.
- Wasp release in all plots Sept-Nov 2020 (130 per plot). N=3 plots per treatment per site.
- Mark and examine 10 shoots per plot Nov. 2020-Sept. 2021; dissect Sept. 2021.

Effect of cutting regime on arundo shoot tip-galling wasp exit hole abundance and density



- Wasp exit holes were 9-fold denser per main shoot and 11-fold denser per main shoot length in double-cut plots than in single-cut plots.
- Two-minute plot counts ignored marked shoots. These counts were 8.6-fold higher in double-cut than single-cut plots, but this difference was not statistically significant.

Integrated chemical-biological control of arundo in the Delta-2017-2022

Ground application



Glyphosate+imazapyr
applied in late
summer or early
autumn

Boom rig application



Before



After



After



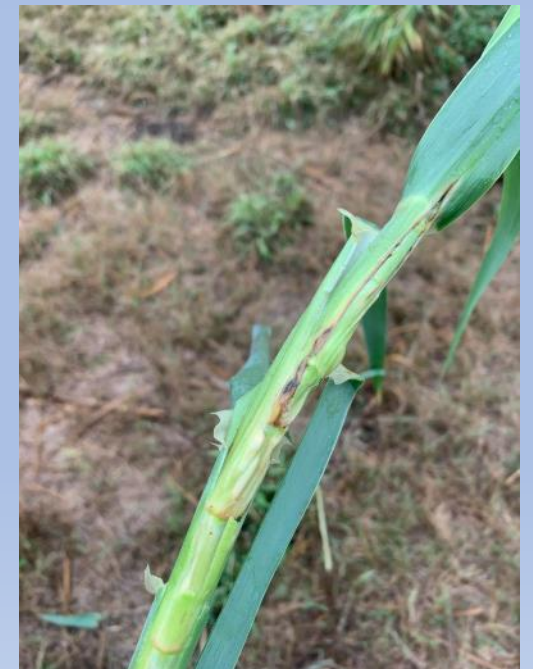
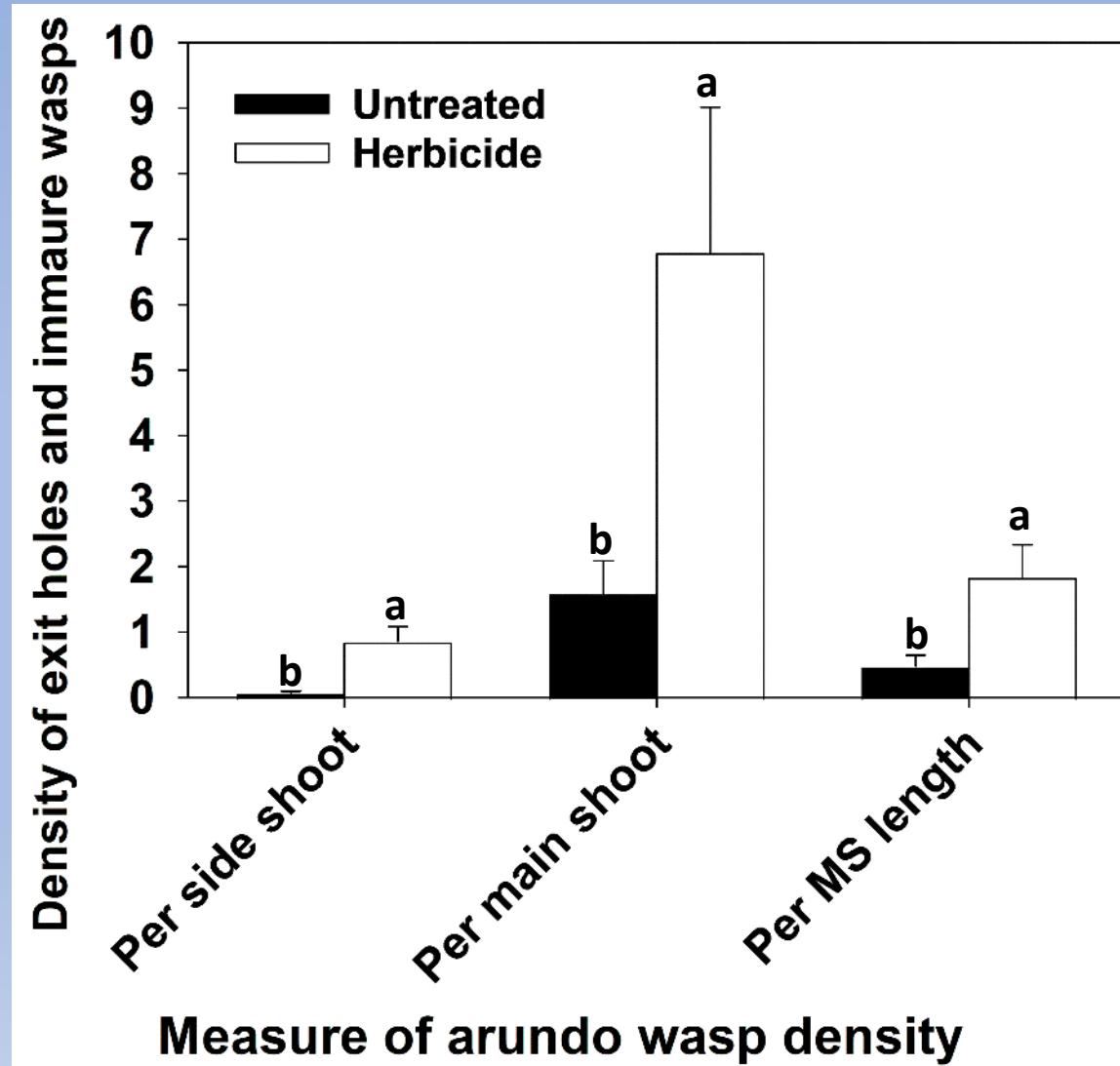
Post-herbicide regrowth 2022



- Examined wasp density in original, untreated biocontrol plots and in post-herbicide regrowth.

Arundo wasp, established at low density on untreated arundo, established more dense populations on post-herbicide regrowth at three Delta sites

- Density of exit holes and immature wasps per side shoot was 12x higher in post-herbicide regrowth ($P=0.03$)
- 4.3x higher as density per main shoot ($P = 0.04$)
- 3.8x higher as density per main shoot length ($P = 0.05$)
- Up to 39-fold higher at one site.



Acknowledgments-Thank You!

Funding and Facilities:



Access to field sites:



Collection of Agents

Dr. Gaylord Desurmont, Dr. Rene Sforza, Dr. Javid Kashefi
(USDA-ARS-EBCL, Montpellier, France)
Matthew Rector (Texas A&M University)

Technical Assistance:

Dr. Scott Portman, Kyra Santa Cruz, Lindsey Hack,
Dr. Michael Pitcairn, Dr. Thomas Jabusch



And private landowners