Insectary Cover Crop Trial – California Almond Orchard

Jessa Kay Cruz, Senior Pollinator Conservation Specialist The Xerces Society, December 2019

Objective: Analyze the multiple natural resource benefits of cover crops designed for pollinator and beneficial insect forage (pollen/nectar) in different cropping systems, and identify some of the motivations for, and barriers to, adoption. Use simple protocols to assess habitat establishment and effects of habitat plantings on water-holding capacity, soil carbon sequestration, and populations of beneficial insects.

County: Merced, CA
Average Annual Precipitation: 9 – 16”
MLRA: 17
Practice: Cover Crop (340)
Dominant Soil Type: Delhi sand
Slope: 0-3%
Aspect: NA
Elevation: 135’
Site Preparation: Herbicide use, mowing, and light cultivation
Planting Method: Broadcast seeded with modified ant-bait spreader (we recommend rolling after broadcast seeding, but it was not possible at this site, due to inadequate equipment).
Seeding Rate: 35 PLS/ft2 (45 PLS/ft2 was used in subsequent plantings and yielded better results). See seed mix details in Tables 1 and 2.
Planting Date: 11/27/17
Acres Planted: 7 acres of cover crop planted in drive rows of a 10.5 acre orchard block.
Previous Site History: Orchard understory managed through regular mowing and herbicide use.
Fertilizer: None
Irrigation: None available for cover crop
Grazing: N/A
Termination Date: 8/2/18
Termination Method: Flail mow

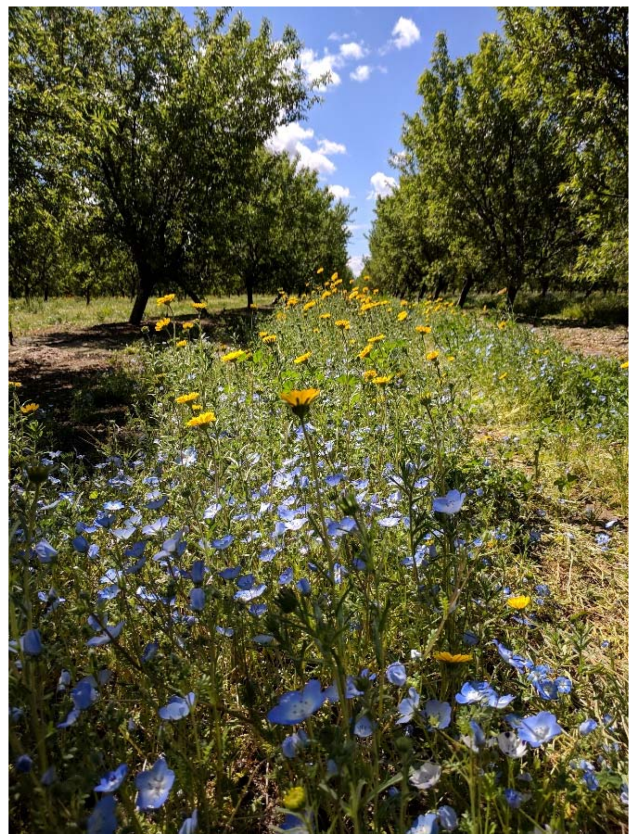

Figure 1: Baby blue eyes (*Nemophila menziesii*) and tidy tips (*Layia platyglossa*) were two valuable native plants used in this almond insectary cover crop field trial.

Introduction

This insectary cover crop field trial was part of a larger project involving the design and implementation of specific insectary habitat features, such as field borders or cover crops, and measuring some of the resource benefits of these features. We worked with seven different growers at nine different sites as part of this overall project. This project encompassed multiple cropping systems, including almonds, walnuts, apples, wine grapes and mixed vegetables.

Selecting appropriate plant materials and/or engineering appropriate seed mixes was a key goal of the project. For this almond orchard field trial, plant species' attractiveness to pollinators and natural enemies was a key consideration. We also considered factors such as height and biomass, because tall, dense plants could potentially increase the risk of frost by blocking air-flow and plants that were too dense or woody could create an abundance of debris to clear away prior to almond harvest. Bloom season was also taken into consideration, such that the cover crop provided bloom immediately after crop bloom and continued for as far into the summer as possible, while still allowing for the cover crop to be terminated in time for harvest. As water use of non-crop species (e.g. habitat) is always a concern and the cover crop area is non-irrigated, drought tolerant wildflowers, especially native wildflowers, were included in the seed mix. Ability to establish quickly and outcompete weeds, likelihood to re-seed, effect on soil health, and the risk of serving as alternate hosts for crop pests or diseases also were taken into consideration.

The resulting seed mix includes brassicas, wildflowers, and legumes. Brassicas were key for overall establishment, as they germinate and bloom early, providing early season nectar and excellent weed competition. The native wildflowers had the benefit of persisting in non-irrigated environments even in drought years, blooming well into the spring and summer even with no supplemental water. The native plants included some of the most important species for native bees. Finally, legumes were included because they provide an inexpensive source of nectar and contribute significantly to soil health. Table 3 (below) provides additional information about the species used in the Almond Orchard Insectary Cover Crop seed mix.

This almond orchard field trial was done on a 60-acre conventional almond orchard, and consisted of two adjacent blocks, totaling approximately 10.5 acres of orchard (7 planted acres). The seed was broadcast using a modified ant-bait spreader (Figure 2). This worked reasonably well, but was difficult to calibrate and resulted in somewhat inconsistent seed distribution. Also, the recommendation was made to use a ring-roller or similar implement to push the seed down into the soil, but the growers lacked the proper equipment. As a result, establishment success was likely reduced because of inadequate seed–soil contact or because or seed may have moved off-site due to wind and run-off from heavy rains post-planting.

Figure 2: Modified ant-bait spreader used for seeding.

We used simple protocols to track the establishment of the habitat areas overall, as well as the establishment of individual species, to help inform seed mix and plant list recommendations. We also used Xerces' *Beneficial Insect Scouting Guide* (**xerces.org/publications/scouting-guides/beneficial-insect-scouting-guide)**, to monitor the habitat areas and a paired control site for eight different beneficial insect groups. Over the course of two years, we conducted this scouting four to five times at each site between March and September. At the end of the project period, we also conducted field soil assessments and soil testing at the project sites and a paired control site, in order to assess the effect of the habitat planting on soil health. Finally, we conducted exit interviews with participating growers to assess some of the reasons that growers adopt these habitat features, as well as some of the barriers and challenges growers face throughout the process.

Results
This site was visited on 3/29/18, 5/9/18, 3/12/19, 4/9/19, and 4/24/19. During each visit, we assessed establishment success and completed the beneficial insect scouting protocol. At the end of the project, we administered the grower survey and conducted the soil health assessment, the results of which are below.

Establishment Success: Establishment of the overall cover crop was scored on a scale of 1 to 5, with 1 indicating no establishment and 5 indicating excellent establishment. Establishment at this almond orchard site was patchy and ranged from poor (2) to good (4). Individual species establishment and bloom time also were tracked. Species were ranked in abundance categories of 'absent', 'sparse', 'present' and 'abundant' and this ranking was used to adjust final recommended seed mixes (Table 2). More details on seed mix composition and seeding rate is in the *Summary and Discussion* section below.

Insect Scouting: Using both floral monitoring and sweep netting, we assessed and recorded populations of the following insect groups: native bee, honey bee, syrphid fly, predatory wasp, spider, minute pirate bug (MPB), lady beetle and lacewing. The project area was paired with a control site on the same property, which consisted of typical resident vegetation growing under the orchard canopy in a separate block (Figures 3 and 4).

Below are the results of the insect scouting for this site. The results of the insect scouting for all groups of beneficial insects combined are shown in Figure 5, while Figures 6 and 7 contain the results with just natural enemies and just pollinators, respectively. As syrphid flies can be both pollinators (as adults) and natural enemies (as larva), they are included in both tables.


Figure 3. Insect scouting habitat area


Figure 4. Insect scouting control site

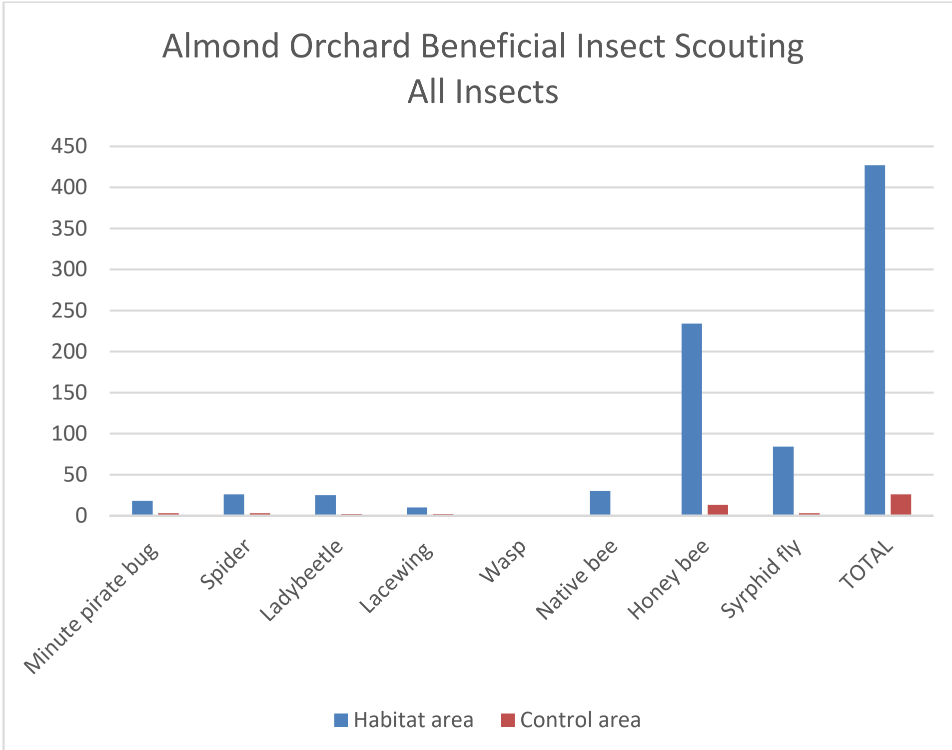

Figure 5: Beneficial insect scouting data from this almond orchard (all insects)

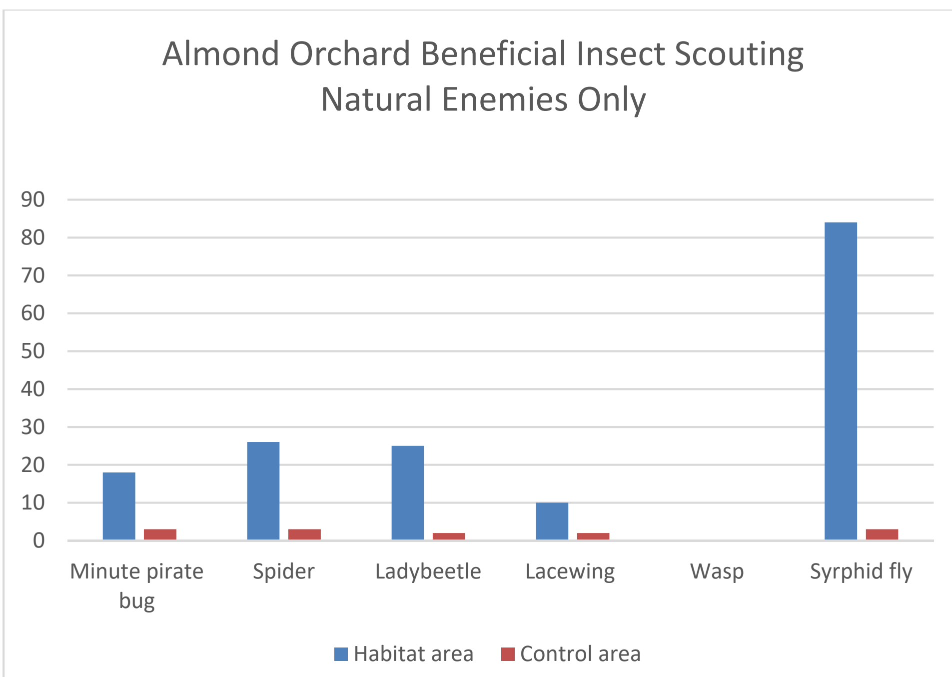

Figure 6: Beneficial insect scouting data from this almond orchard (natural enemies only)

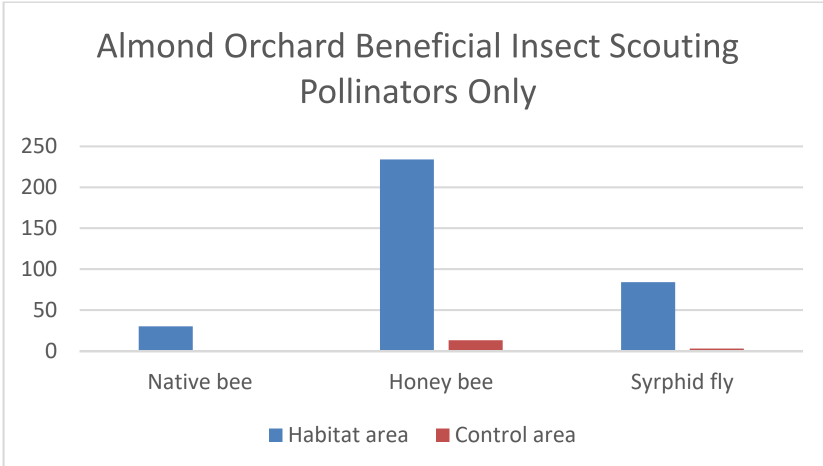

Figure 7: Beneficial insect scouting data from this almond orchard (pollinators only)

Soil Health Monitoring: Monitoring took place in a cover-cropped field (which served as the control field) and in an adjacent field that did not receive a cover crop planting. At both fields we assessed ten different soil attributes using the NRCS soil health field assessment. We also submitted soil samples for two different laboratory tests. The first test measured water holding capacity (performed by A&L Western Agricultural Laboratories of Modesto CA). The other was the Haney test (performed by Ward Laboratories of Kearney NE), which measured microbial activity and nutrients to provide a general soil health score.

Table 1: Case Study Soil Test Results: Below are the results from the three different soil tests conducted at the case study orchard.

		Cover Crop	Control
Water Holding	Water holding capacity	35%	32%
	Available water (in/ft)	1.0	1.0
Haney Test	pH	6.7	7.0
	Organic matter (%LOI)	0.9	1.1
	Respiration (ppm CO2/24 hr)	31.3	26.2
	Organic N (ppm)	4.6	10.6
	Organic C (ppm)	133	104
	OC : ON	28.9	9.9
	Soil Health	6.26	5.77
Field Assessment	Compaction	3	3
	Structure	2	1.5
	Crusts	3	3
	Residue	N/A*	N/A*
	Roots	1	1
	Pores	1.5	1
	Earthworms	1	1
	Biological acivity	1	1
	Smell	2	N/A**
	Aggregate stability	2	3
	Mean field score (max = 3)	**1.8**	**1.8**

** Almond orchards scrape to remove residue before harvesting the crop*
***Soil was too dry to smell*

Summary and Discussion

Establishment Success: Establishment at this site was about average, compared to other sites in this project. It is hard to determine specifically why establishment was patchy, but it is likely that inadequate seeding equipment played a role. The modified ant-bait spreader was not an ideal replacement for a well-designed seeder, and there was no ring-roller or similar implement available to push the seed down into the soil after planting, so this step was skipped. It should be noted that when broadcast seeding, the final step of rolling to push the seed into the soil is an important factor in successful establishment.

Management of the cover crop posed some challenges, as some weeds germinated in the cover crop area along with the desirable species. Grass-weeds were managed through the application of selective herbicides. Early-season broadleaf weeds, such as *Malva sp*., were managed through an early-season high-mow (approximately 1ft), which knocked back the weeds without sacrificing the cover crop species. Later season weeds were managed through targeted (hot-spot) mowing.
Termination: Termination was primarily done through flail mowing in mid-summer, when the cover crop species had gone to seed and begun senescing. Many of the species in the mix successfully re-seeded in year 2, particularly the native wildflowers. That said, re-seeding was most successful in areas that had strong initial establishment the first year, while areas that were sparse in Year 1 were even more sparse in Year 2.

Plant species and seed mix recommendations: Cover crop species abundance data from this site and other sites in this project were utilized to make adjustments to the seed mix specifications (see Tables 1 and 2, below). For example, if a species was consistently ranked 'absent' or 'sparse', that species was either removed from the mix or the individual seeding rate was increased. We made these decisions based on factors such as cost, initial seeding rate, and beneficial insect value. The establishment data from all projects together helped informed subsequent seed mix specifications, including species selection, relative percentage of each species in the seed mix, and overall recommended seeding rates (see Table 2 below for final almond orchard recommendation).

This larger project resulted in the creation of three different seed mixes: one for almond orchards or other scenarios where producers want early maturing annuals that that leave little residue into the summer; one for vineyards or apple orchards, where permanent cover is desired; and one for walnut orchards where shade and leaf duff are factors. More information and specifications for these different cover crop seed mixes can be found at **xerces.org/pollinator-conservation-resources/California**.

Table 1. Seed mix used for initial almond orchard field trial: This was the original seed mix utilized for this almond orchard project. After this trial and a number of others like it, the seed mix was altered slightly to develop final recommendations for cover crop planting in almond orchards. These final specifications can be found in Table 2.

Scientific Name	Common Name	% Seed Mix (seed/ft^2)	PLS Seeds/ft^2	# Seeds/Lb	Seed Rate PLS lbs/acre
Brassica hirta	White mustard	3.0%	1.05	73,000	0.63
Calandrinia menziesii	Red maids	5.0%	1.75	545,319	0.14
Collinsia heterophyllus	Chinese houses	9.0%	3.15	340,000	0.40
Eschscholzia californica	California poppy	9.0%	3.15	260,193	0.53
Layia platyglossa	Tidy tips	3.0%	1.05	287,140	0.16
Linum usitatissimum	Common flax	13.0%	4.55	82,000	2.42
Lobularia maritima	Alyssum	15.0%	5.25	1,000,000	0.23
Nemophila maculata	Five spot	3.0%	1.05	60,000	0.76
Nemophila menziesii	Baby blue eyes	9.0%	3.15	210,000	0.65
Phacelia ciliata	Great valley phacelia	4.0%	1.40	175,619	0.35
Raphanus sativis	Tillage radish	4.0%	1.40	28,500	2.14
Trifolium incarnatum	Crimson clover	10.0%	3.50	98,000	1.56
Trifolium mechelianum	Balansa clover	10.0%	3.50	650,000	0.23
Vicia sativa	Common vetch	3.0%	1.05	7,000	6.53
TOTALS:		**100.00%**	**35.00**		**16.73**

Table 2: Recommended seed mix for an Almond / Orchard Annual Insectary Cover Crop: This mix contains native and non-native forbs, brassicas, and legumes. It consists of spring and early-summer blooming annuals, and is designed for almond orchards or other situations where early maturing annuals are desired. Most of the species break down quickly after mowing. If managed properly, many species self-sow. This seed mix is available for purchase through S&S seeds.

Scientific Name	Common Name	% Seed Mix (seed/ft^2)	PLS Seeds/ft^2	# Seeds/Lb	Seed Rate PLS lbs/acre
Brassica hirta	White mustard	4.0%	1.80	73,000	1.07
Eschscholzia californica	California poppy	10.0%	4.50	260,193	0.75
Layia platyglossa	Tidy tips	5.0%	2.25	287,140	0.34
Linum usitatissimum	Common flax	12.0%	5.40	82,000	2.87
Lobularia maritima	Alyssum	12.0%	5.40	1,000,000	0.24
Nemophila menziesii	Baby blue eyes	10.0%	4.50	210,000	0.93
Phacelia tanacetifolia	Tansy phacelia	5.0%	2.25	330,000	0.30
Raphanus sativis	Tillage radish	4.0%	1.80	28,500	2.75
Trifolium incarnatum	Crimson clover	12.0%	5.40	98,000	2.40
Ammi majus	Bishop's weed	8.0%	3.60	692,000	0.23
Clarkia unguiculata	Elegant clarkia	14.0%	6.30	1,300,000	0.21
Vicia sativa	Common vetch	4.0%	1.80	7,000	11.20
TOTALS:		**100.00%**	**45.00**		**23.29**

Table 3: Almond/ Orchard Insectary Cover Crop Seed Mix: Plant Species Information

Scientific Name	Common Name	Annual / Perennial	Native / Non-native	Legume, Brassica, Wildflower	Bloom Time*
Brassica hirta	White mustard	Annual	Non-native	Brassica	Early
Eschscholzia californica	California poppy	Annual	Native	Wildflower	Early
Layia platyglossa	Tidy tips	Annual	Native	Wildflower	Early
Linum usitatissimum	Common flax	Annual	Non-native	Wildflower	Early / mid
Lobularia maritima	Alyssum	Annual	Non-native	Wildflower	Early / mid
Nemophila menziesii	Baby blue eyes	Annual	Native	Wildflower	Early
Phacelia tanacetifolia	Tansy phacelia	Annual	Native	Wildflower	Early / mid
Raphanus sativis	Tillage radish	Annual	Non-native	Brassica	Early
Trifolium incarnatum	Crimson clover	Annual	Non-native	Legume	Early / mid
Ammi majus	Bishop's weed	Annual	Non-native	Wildflower	Mid
Clarkia unguiculata	Elegant clarkia	Annual	Native	Wildflower	Mid
Vicia sativa	Common vetch	Annual	Non-native	Legume	Early

*Bloom Times: Early = Feb through April; Mid = May through July; Late = Aug through Oct

<u>Insect Scouting</u>: Overall, sixteen times the number of beneficial insects were found in the cover crop areas as compared to the control site. Honey bees were the most abundant insect monitored at this site, followed by syrphid flies, native bees and spiders, respectively. These results differ slightly from the aggregated results from all sites combined, where there were approximately 24x the number of beneficial insects in the habitat areas as compared to the control site. Honey bees were the most abundant insect found in all sites combined, followed by native bees, syrphid flies and spiders. Syrphid flies are both pollinators and natural enemies, while spiders and ladybeetles are excellent general predators. Below are the aggregate results of the insect scouting at all sites for this project combined.

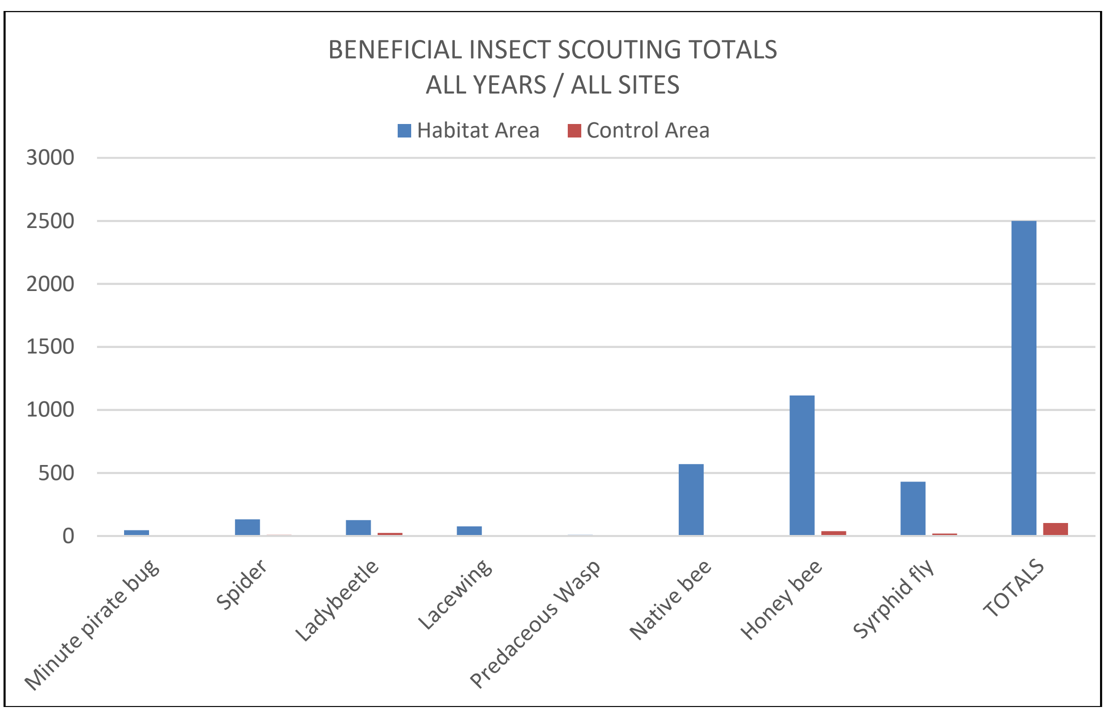

Figure 8: Beneficial insect scouting data (all sites combined)

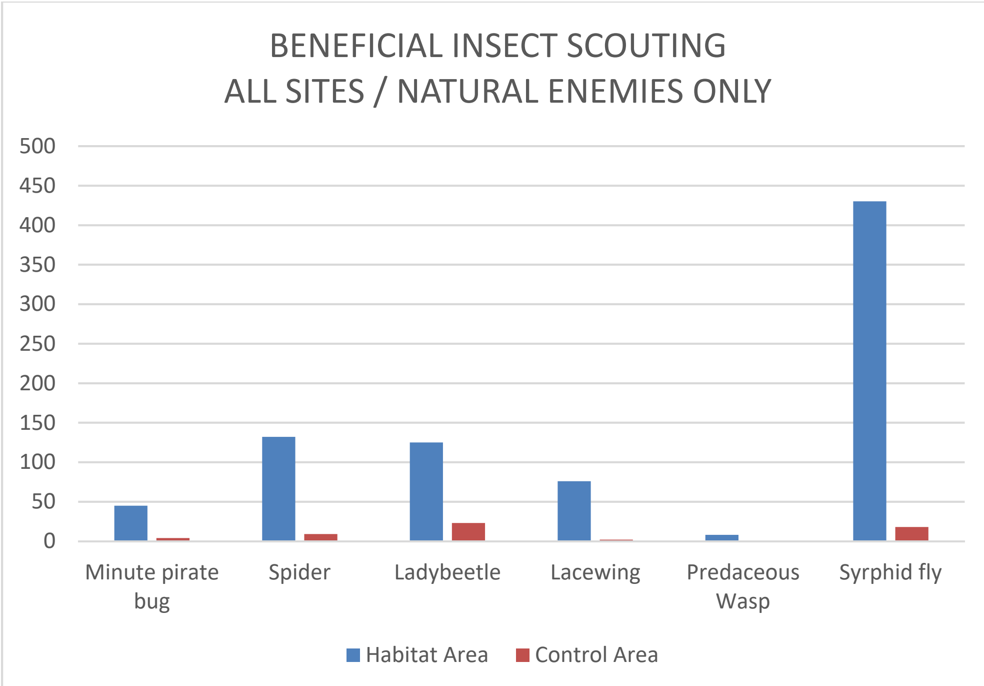

Figure 9: Beneficial insect scouting data (all sites combined, natural enemies only)

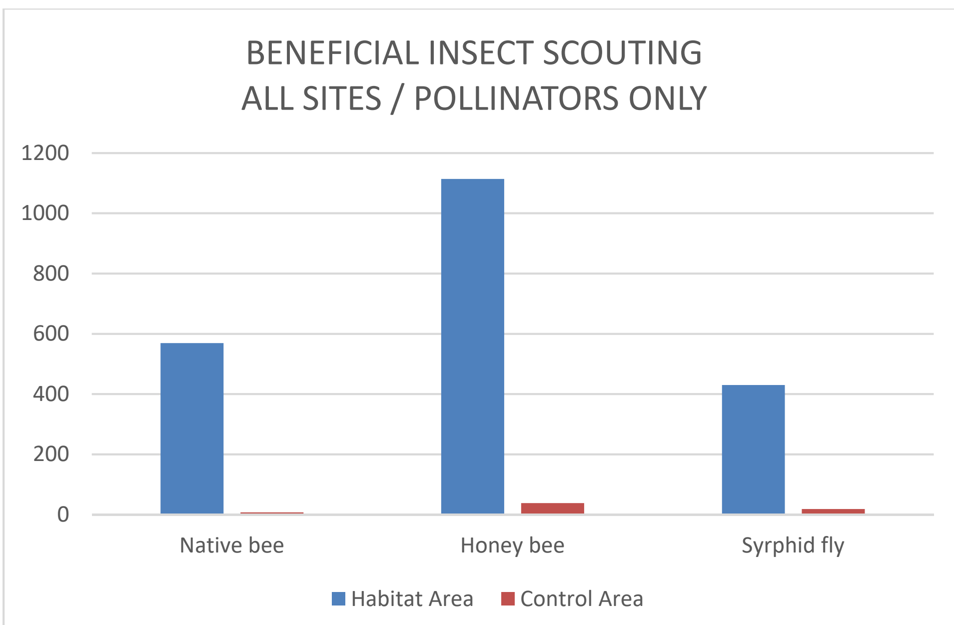

Figure 10: Beneficial insect scouting data (all site combined, pollinators only)

Soil Health Monitoring:

Case study cover cropped area vs. case study control area: The cover cropped and control areas on the case study orchard had few differences in their water holding capacity and observable features. However, the Haney test results reveal some anecdotal differences between the case study's two sampled areas. For example, the cover cropped field had a lower nitrogen concentration, a higher carbon concentration, and a much higher ratio of carbon to nitrogen as compared to the untreated field. The cover cropped field also had a somewhat higher soil respiration value, indicating a greater abundance of microbial life in the soil. The soil health rating generates a score based on the respiration rate, as well as the soil's carbon and nitrogen balance, with a general goal for a score of >7. Neither of the case study's fields received a health score above seven. This may be in part due to both fields undergoing the common practice of scraping and leveling the rows between trees to prepare for almond harvest. These activities can disturb the soil structure and microbial community that were built up earlier in the season. Additionally, in spite of having a favorable carbon to nitrogen ratio both case study fields had very low organic matter. It is possible that the case study orchard's soil microbe community (and consequently its soil health score) are inhibited by a lack of organic matter to provide an ongoing food and habitat source for soil life.

Case study site vs. all other almond sites: In addition to this case study orchard, paired fields were surveyed on two additional almond orchards (Orchard A and Orchard B in Table 4, below). These additional orchards had clay loam soil types, while the case study site had sandy soil. At all three orchards, the cover crops were initially planted in 2017, allowed to re-germinate in 2018, and then sampled after termination in 2019.

This case study orchard had the lowest water holding capacity, organic matter content, carbon concentration, and overall soil health of the three orchards sampled. However, the case study's sandy soils may predispose it to score poorly in these areas so these results are not surprising.

Orchard A showed the most dramatic differences between the cover cropped and control fields. Orchard A also received the most favorable Haney Test scores of the three orchards, including an organic matter content in the cover cropped field that is remarkably high for the region. These more easily observable differences between fields in Orchard A may be due to a starting condition of soil with a higher organic matter content, which would allow cover crops to create a more noticeable benefit.

The range of test values in the case study orchard and Orchard B dd not differ noticeably. Unexpectedly, however, Orchard B's control field had higher soil health values than its cover cropped field. The most noticeable difference was the respiration rate, which was nearly double in the control field. A potential explanation for this phenomenon may be the wet conditions during sampling; the control site's soil had a putrid smell indictive of anaerobic conditions. Anaerobic bacteria respirate carbon dioxide too, which could explain the increased respiration (and consequently soil health) values. Further study at this site would allow us to determine whether Orchard B's results were anomalous or describe a story that our current data are not complete enough to tell.

Conclusion: Healthy soil can take many years to build. It is possible that continued cover cropping over time will allow the case study orchard to build up enough of a community of soil life that a noticeable difference between habitat and control conditions becomes apparent in future years.

Table 4: Aggregated Soil Test Results: Below are the results from the three different soil tests conducted at the case study orchard and two additional almond orchards.

		CASE STUDY		Orchard A		Orchard B	
		Cover Crop	**Control**	**Cover Crop**	**Control**	**Cover Crop**	**Control**
Water Holding	Water holding capacity	35%	32%	55%	45%	42%	45%
	Available water (in/ft)	1.0	1.0	1.7	1.4	1.3	1.3
Haney Test	pH	6.7	7.0	7.2	6.9	7.2	7.1
	Organic matter (%LOI)	0.9	1.1	5.4	2.4	1.6	1.9
	Respiration (ppm CO2/24 hr)	31.3	26.2	170.9	58.9	26.4	42.5
	Organic N (ppm)	4.6	10.6	16.3	10.6	8.6	10.0
	Organic C (ppm)	133	104	357	218	167	180
	OC : ON	28.9	9.9	21.9	20.5	19.5	18
	Soil Health	6.26	5.77	23.01	11.33	6.84	8.85
Field Assessment	Compaction	3	3	2	1	3	3
	Structure	2	1.5	2	1.5	2.5	1.5
	Crusts	3	3	3	3	3	3
	Residue	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
	Roots	1	1	1	1	2	1
	Pores	1.5	1	2	1.5	2.5	1
	Earthworms	1	1	1.5	2	2	2
	Biological acivity	1	1	1	1	2.5	1.5
	Smell	2	N/A**	2	2	2.5	1
	Aggregate stability	2	3	1.5	3	3	1
	Mean field score (max = 3)	**1.8**	**1.8**	**1.8**	**1.8**	**2.6**	**1.7**

** Almond orchards scrape to remove residue before harvesting the crop*
***Soil was too dry to smell*

Participating Grower Survey Feedback: Below are the aggregated results of the survey, which was completed by five participating growers at the end of the project. In parenthesis is the percentage of growers surveyed that included that particular answer in their response. The feedback from the grower partner at this site generally matched the combined feedback from all growers.

1) **Top five objectives for cover-cropping / planting field borders**
    a. Increase soil organic matter *(100%)*
    b. Attract pollinators and beneficial insects *(80%)*
    c. Improve water infiltration *(60%)*
    d. Reduce compaction *(60%)*
    e. Improve soil health *(40%)*
2) **Top three concerns / barriers prior to project**
    a. Increased workload to manage cover crop (*80%*)
    b. Uncertainty about which species to plant (*60%*)
    c. Fitting into crop management or crop rotation practices (*60%*)
3) **Top three concerns/ barriers now that project is complete**
    a. Fitting into crop management practices (*40%*)
    b. Increased workload to manage cover crop (*40%*)
    c. Increased risk of frost in adjacent crops (*40%*)
    d. Cost / unknown cost benefit (*40%*)
    e. Access to equipment for planting or managing cover crops (*40%*)

4) **Have you planted cover crops / habitat planted prior to this project?**
    a. No (60%) / Yes (*40%)*
5) **How likely are you to continue planting cover crops / habitat**
    a. Very likely (*100%)*
6) **What would be most helpful to support you in continuing to plant or maintain cover crops on your farm (top three)?**
    a. Continued technical support on what species to plant (*100%*)
    b. Financial support for cost of seed / plants (*80%*)
    c. Financial / physical support with planting or managing habitat (including cover crop equipment) (*60%*)
7) **What benefits did you experience from planting cover crops?**
    a. Increase in beneficial insect populations (*80%*)
    b. Benefits to managed honey bee hives (*40%*)
    c. Soil health benefits (*40%*)
    d. Reduction in insecticide applications (*20%*)
8) **What challenges / unwanted outcomes did you experience from planting cover crops?**
    a. Increased workload (*60%*)
    b. Managing weeds (*40%*)
    c. Clearing away debris *(40%)*
    d. Planting equipment and timing *(40%)*

<u>Additional Feedback</u>: A series of outreach events related to insectary cover-cropping were conducted as part of this project. A survey was sent out to participants from several workshops to get additional feedback on goals, objectives and hurdles related specifically to cover-cropping. Twenty-one people responded, which represents a 46% response rate. Below are the results, which are similar to the results of the individual grower surveys.

1) **How would you describe yourself?**
    a. NRCS or RCD staff *(66.7%)*
    b. Educator or student *(23%)*
    c. Farmer / rancher *(9.6%)*
    d. Conservation non-profit staff *(9.6%)*
2) **Which FIVE objectives or potential benefits of cover-cropping are most important to you or the growers you work with? *Please select only your top five choices.***
    a. Increase soil organic matter (*61.9%)*
    b. Improve water infiltration (*61.9%)*
    c. Suppress weeds *(47.6%)*
    d. Attract pollinators / beneficial insects *(47.6%)*
    e. Improve soil health *(47.6%)*
3) **Several barriers to planting cover crops have been identified. Of these barriers, which THREE most concern you or the growers you work with? *Please select only three options.***
    a. Fitting into crop rotation or crop management practices *(90.4%)*
    b. Increased workload to manage cover crop *(52.4%)*
    c. Cost / unknown cost benefit *(52.4%)*
4) **Did this workshop make you more likely to plant a cover crop, or encourage those you work with to plant a cover crop, in the near future?**
    a. Yes *(85.7%)* / No (*14.3%)*
5) **Did this workshop address any of the barriers to cover crop planting you have, or have heard**

expressed by growers you work with?

a. Yes (81%) / No (19%)

6) Did this workshop expose you to new ideas about cover cropping?

a. Yes (90.5%) / No (9.5%)

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AUTHORS: Jessa Kay Cruz, Mace Vaughan, Kitty Bolte and Kathryn Prince of The Xerces Society for Invertebrate Conservation