Insectary Cover Crop Trial – California Apple Orchard

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Objective: Analyze the multiple natural resource benefits of pollinator habitat features 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: Santa Cruz
Average Annual Precipitation: 35-60”
MLRA: 14
Practice: Cover Crop (340)
Dominant Soil Type: Elder sandy loam
Slope: 2 – 30%
Aspect: NA
Elevation: 390’
Site Preparation: Herbicide use, mowing, light cultivation
Planting Method: Hand-seeded using belly grinders, followed up with ring rolling.
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: 11/20/17 and 11/27/18 (replant)
Acres Planted: 1.6 acres planted in drive rows of a 2-acre orchard block.
Previous Site History: Orchard understory, managed through mowing and herbicide use
Fertilizer: None
Irrigation: None available for cover crop
Grazing: N/A
Termination Date: 5/31/2019
Termination Method: Mow

Figure 1: Baby blue eyes (*Nemophila menziesii*) and California poppy (*Eschscholzia californica*) were two valuable native plants used in this apple orchard 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, where we measured the diverse 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 for target crops and landscapes was a key goal of the project. For this apple orchard field trial, plant species’ attractiveness to pollinators and natural enemies was a key consideration. Bloom season was also taken into consideration, such that the cover crop provided bloom both before and after crop bloom. 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 also 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 provides additional information about the species used in the Vineyard/ Orchard Perennial Insectary Cover Crop seed mix.

This field trial was done in a 22-acre conventional apple orchard. Cover crops were planted in two adjacent blocks, totaling approximately 2 acres of orchard (1.6 planted acres of cover). Drive rows were lightly disked prior to planting and seed was distributed using belly grinders. After seeding, we made several passes with a small tractor-mounted ring roller to ensure good seed to soil contact.

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 paired control sites 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 conducted field soil assessments and soil testing in the planted areas and paired control sites, 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 4/16/18, 5/21/18/ and 5/7/19. 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 apple orchard during the first year (2018) was poor to fair (2.5). There was patchy cover crop germination and grass competition from past cover crop plantings. The site was re-planted in the following year in order to improve establishment. During the second year of this project (2019), establishment was fair to good (3.5). 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 2 and 3).

Figure 2. Insect scouting control site

Figure 3: Insect scouting habitat area

Below are the results of the insect scouting for this site. The results of the insect scouting for all groups of beneficial insects combined is shown in Figure 4, while Figures 5 and 6 contain the results with only natural enemies and only pollinators, respectively. As syrphid flies can be both pollinators (as adults) and natural enemies (as larva), they are included in both tables.

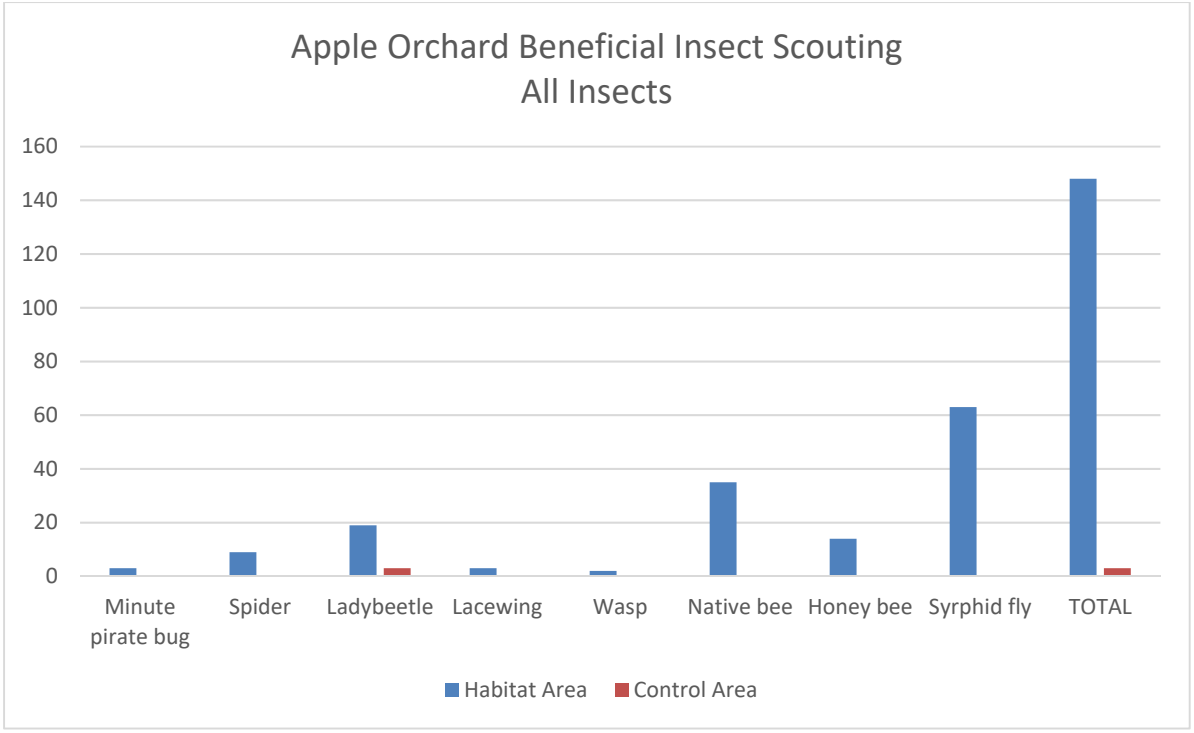

Figure 4: Beneficial insect scouting data from this apple orchard (all insects)

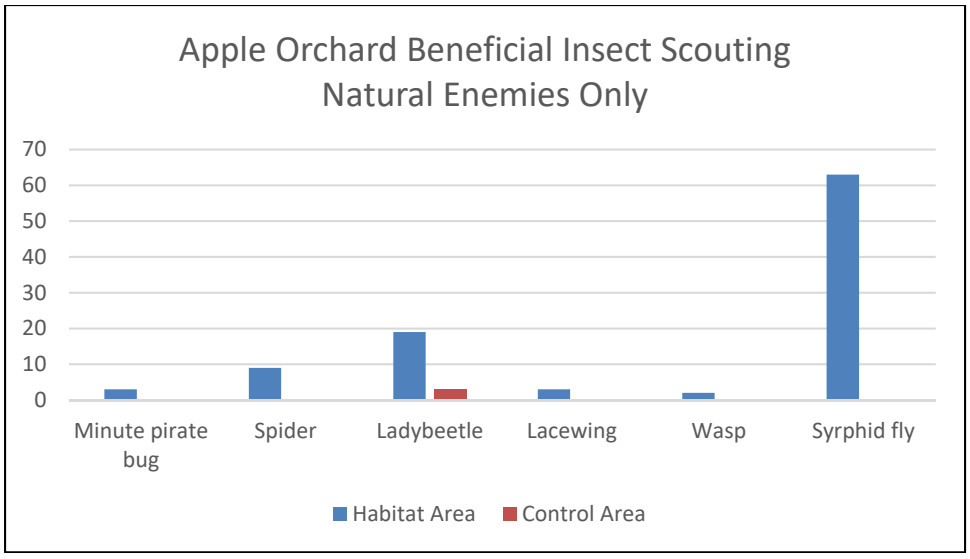

Figure 5: Beneficial insect scouting data from this apple orchard (natural enemies only)

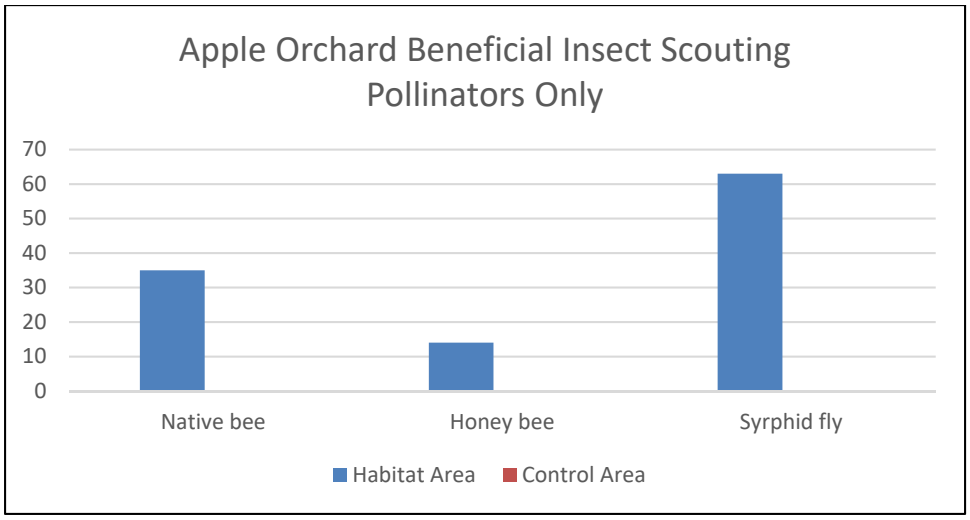

Figure 6: Beneficial insect scouting data from this apple orchard (pollinators only)

Soil Health Monitoring: We were not able to include a soil health monitoring component in this case study. However, as an additional component of this project four Central California farm sites with habitat plantings received soil testing. The farm sites' soils ranged from sandy to clay loam. Three of the four sites were conventional almond orchards in the central valley that contained a cover cropped field paired with an un-cover cropped control field. The fourth site was an organic vegetable farm near the central coast with a permanent habitat area that was paired with an un-planted control field. Every field received a water holding capacity test, soil health test (the Haney test), and a field assessment to score physical features.

Summary and Discussion

Establishment Success: Establishment at this site was slightly lower than at the other sites in this project. The planting equipment used was not ideal, as belly-grinders are difficult to calibrate for large areas, and the added challenge of sloped areas and a seed bank from previously planted grasses may have contributed to lower germination rates. Weed and grass competition was managed through a high mow (approximately 1ft) of the entire area in mid-April both years (2018 and 2019). The cover crops were mowed a second time in the summer to clear away vegetation for harvest.

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 apple orchard field trial: This was the original seed mix utilized for this apple 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	PLS lbs/acre
Calendula officinalis	Winter marigold	8.0%	2.80	65,000	1.88
Clarkia unguiculata	Elegant clarkia	19.0%	6.65	1,214,672	0.24
Eschscholzia californica	California poppy	14.0%	4.90	260,193	0.82
Layia platyglossa	Tidy tips	3.0%	1.05	287,140	0.16
Linum usitatissimum	Common flax	12.0%	4.20	82,000	2.23
Lobularia maritima	Alyssum	19.0%	6.65	1,000,000	0.29
Nemophila menziesii	Baby blue eyes	12.0%	4.20	210,000	0.87
Phacelia californica	California phacelia	8.0%	2.80	242,410	0.50
Raphanus sativus	Tillage radish	5.0%	1.75	28,500	2.67
TOTALS:		**100.00%**	**35.00**		**9.66**

Table 2. Recommended Seed Mix for Vineyard / Orchard Perennial Insectary Cover Cropping: This mix contains native and non-native forbs and brassicas. It consists of both perennial and annual species and provides bloom from spring through fall, as well as winter cover. It is designed for vineyards, apple orchards, or other situations where perennial cover and long season bloom are desired. This mix was used in the 2018 re-plant for this project. 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	PLS lbs/acre
Achillea millefolium	Yarrow	9.0%	4.05	3,000,000	0.06
Clarkia unguiculata	Elegant clarkia	16.0%	7.20	1,214,672	0.26
Eschscholzia californica	California poppy	8.0%	3.60	260,193	0.60
Grindelia camporum	Gumplant	8.0%	3.60	201,989	0.78
Layia platyglossa	Tidy tips	5.0%	2.25	287,140	0.34
Linum usitatissimum	Common flax	13.0%	5.85	82,000	3.11
Lobularia maritima	Alyssum	12.0%	5.40	1,000,000	0.24
Phacelia tanacetifolia	Tansy phacelia	8.0%	3.60	330,000	0.48
Nemophila menziesii	Baby blue eyes	6.0%	2.70	210,000	0.56
Phacelia californica	California phacelia	6.0%	2.70	242,410	0.49
Brassica hirta	White mustard	5.0%	2.25	73,000	1.34
Raphanus sativus	Tillage radish	4.0%	1.80	28,500	2.75
TOTALS		**100%**	**45.00**		**11.00**

Table 3 Vineyard/Orchard Perennial 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
Achillea millefolium	Yarrow	Perennial	Native	Wildflower	Mid to late
Clarkia unguiculata	Elegant clarkia	Annual	Native	Wildflower	Early / mid
Eschscholzia californica	California poppy	Annual	Native	Wildflower	Early to mid
Grindelia camporum	Gumplant	Perennial	Native	Wildflower	Mid to late
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	Mid
Phacelia tanacetifolia	Tansy phacelia	Annual	Native	Wildflower	Early
Nemophila menziesii	Baby blue eyes	Annual	Native	Wildflower	Early
Phacelia californica	California phacelia	Perennial	Native	Wildflower	Mid
Raphanus sativus	Tillage radish	Annual	Non-native	Brassica	Early

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

Insect Scouting: Overall, we found forty-nine times the number of beneficial insects in the cover crop area as compared to the control area. Syrphid flies were the most abundant insect group detected, followed by native bees, lady beetles, and honey bees, respectively. These results differ slightly from the aggregated results from all sites combined, where there were approximately twenty-four times 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.

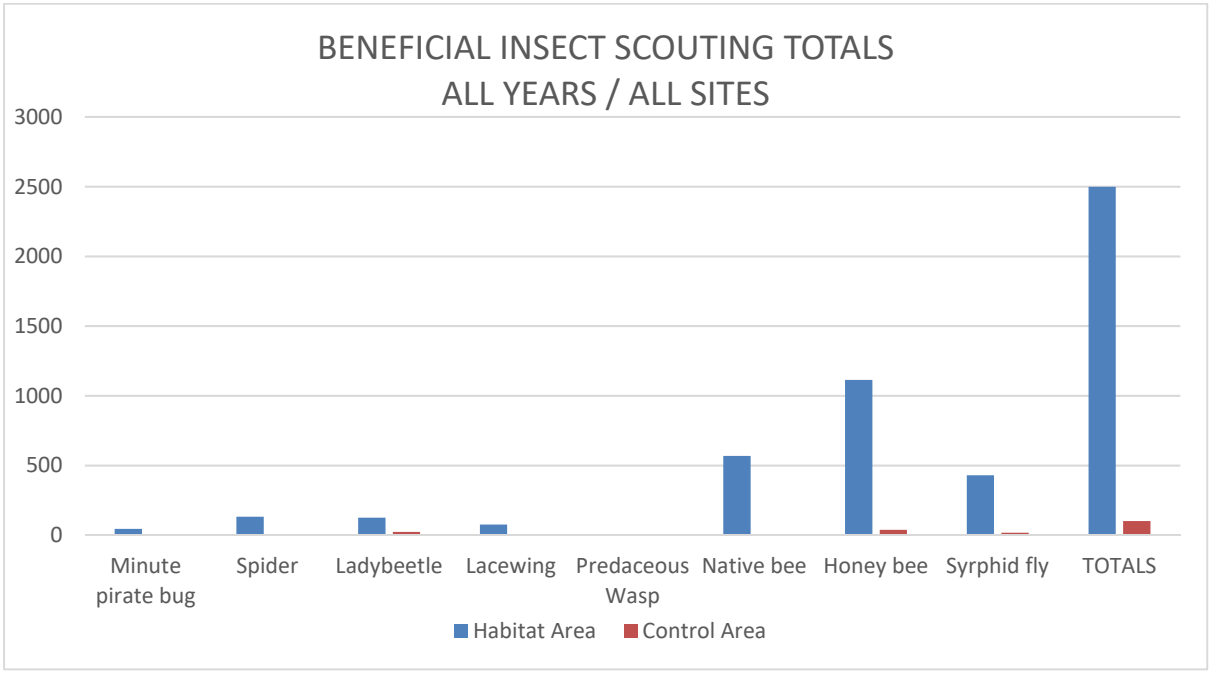

Figure 7: Beneficial insect scouting data (all sites combined)

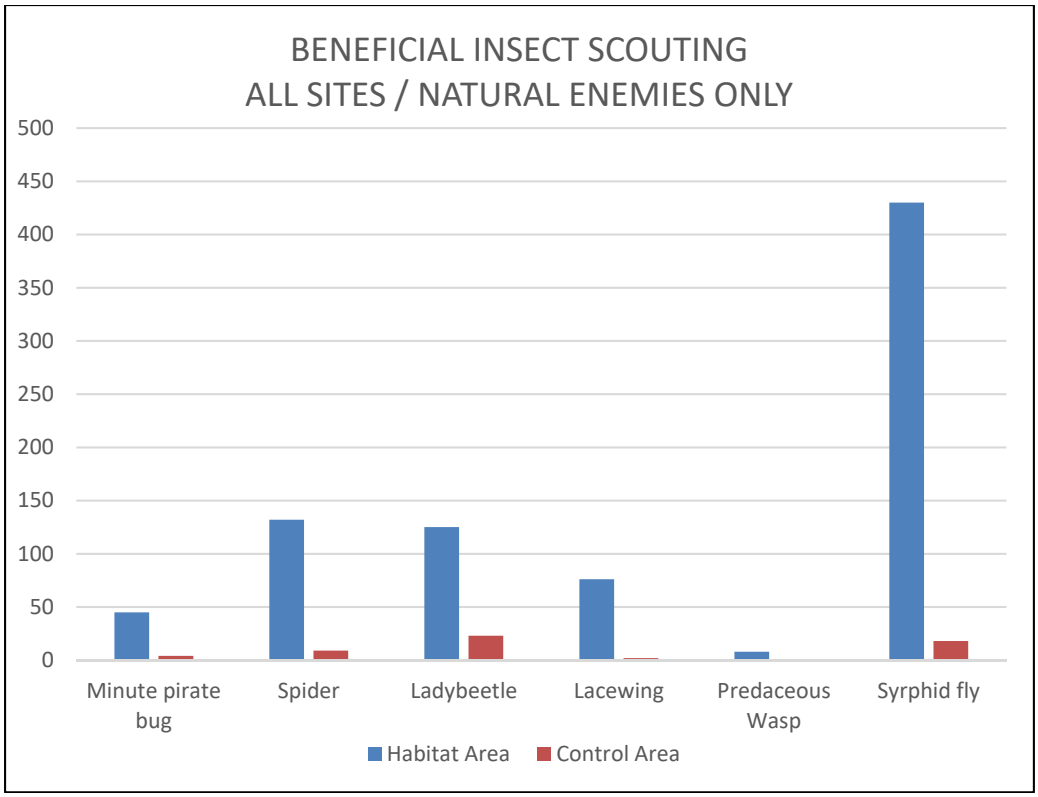

Figure 8: Beneficial insect scouting data (all sites combined, natural enemies only)

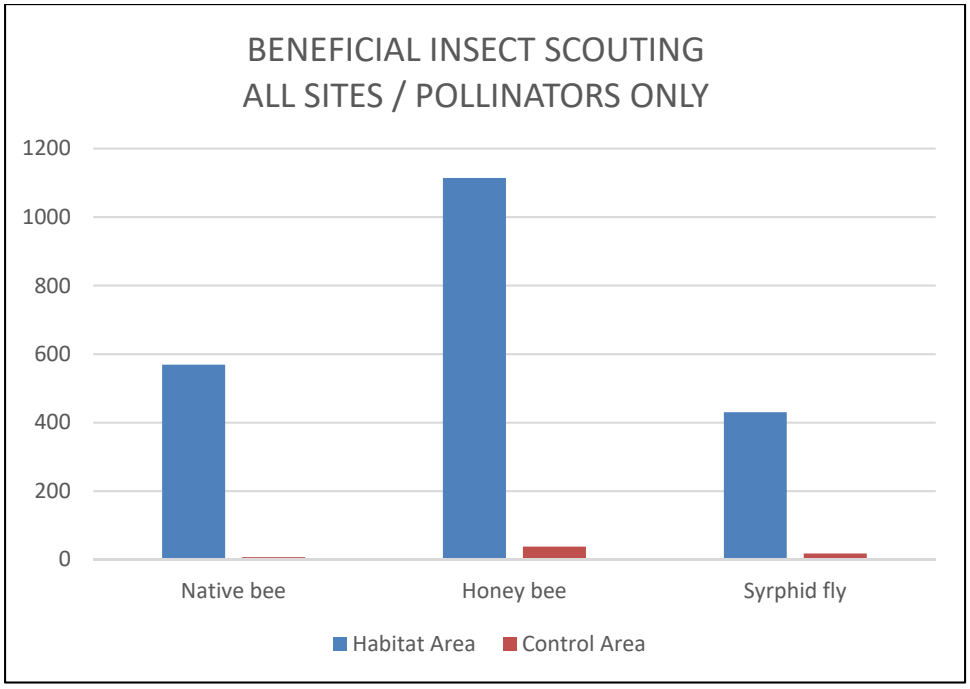

Figure 9: Beneficial insect scouting data (all sites combined, pollinators only)

Soil Health Monitoring: Some anecdotal differences can be observed between the habitat plantings and control conditions on all the sampled farms. For example, the habitat areas scored as healthier than the control areas in nearly every criterion of the field assessment. These differences resulted in noticeably higher mean field assessment scores in the habitat areas. The Haney test's reported soil health scores and soil respiration values were also somewhat higher in the habitat areas as compared to the controls. A higher soil respiration value indicates a greater abundance of microbial life in the soil. The soil health rating generates a score based on this respiration rate, as well as the soil's carbon and nitrogen balance, with a general goal for a score of >7. These differences in soil health and structure in the habitat planting may be due in part to the permanent presence of living roots that were missing in the control field. As living plants take in carbon dioxide from the atmosphere, the roots also pass carbon into the soil. Some of this plant-supplied soil carbon serves as fodder to build up populations of soil organisms. As roots, soil organisms, and organic matter increase they bind the soil together, creating air pockets and aggregates that sequester carbon.

Had the present case study included a soil sampling component, we can assume that similar soil health differences would have been observed here. It's important to note, however, that building soil health is a slow process that can take many years. If the same sites sampled in 2019 continue to bear habitat features each year, it is possible that more dramatic differences between conditions will occur in the future.

Table 4: Soil Test Results: Below are the results from soil tests conducted at a vegetable farm site and the mean results of soil tests conducted at three almond orchard sites.

		VEGETABLE FARM		ALMOND ORCHARD	
		Perennial Habitat (n=1)	Control (n=1)	Cover Crop (n = 3)	Control (n = 3)
Water Holding	Water holding capacity	41%	43%	44%	40%
	Available water (in/ft)	1.23	1.29	1.3	1.2
Haney Test	pH	7.4	7.3	7.0	7.0
	Organic matter (%LOI)	2.1	2.2	2.6	1.8
	Respiration (ppm CO2/24 hr)	45.7	29.3	76.2	42.5
	Organic N (ppm)	46.5	42.4	9.8	10.4
	Organic C (ppm)	229	205	219	167
	OC : ON	4.9	4.8	23.4	16.1
	Soil Health	**9.6**	**7.5**	**12.0**	**8.7**
Field Assessment	Compaction	3	3	2.7	2.3
	Structure	3	1	2.2	1.5
	Crusts	3	3	3	3
	Residue	3	1	N/A*	N/A*
	Roots	2.5	1	1.3	1
	Pores	2.5	1	2	1.2
	Earthworms	2	1	1.5	1.7
	Biological acivity	2	1	1.5	1.2
	Smell	2	2	2.2	1.5
	Aggregate stability	3	2.5	2.2	2.3
	Mean field score (max = 3)	**2.6**	**1.7**	**2.1**	**1.7**

** Almond orchards scrape to remove residue before harvesting the crop*

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%)*

Additional Feedback: 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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