

Project Title: Assessing refugia plantings for biocontrol services

Report Type: Final Project Report

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Project Duration: 2 Years

Total Project Request for Year 1 Funding: \$48,401

Total Project Request for Year 2 Funding: \$50,235

Other related/associated funding sources: Awarded

Funding Duration: 2022–2025

Amount: \$249,560

Agency Name: Washington State Department of Agriculture Specialty Crop Block Grant

Notes: Ensuring reliable pollination for Washington apples with cultural practices and conservation.

Other related/associated funding sources: Applied, not funded

Funding Duration: 2025

Amount: \$24,000

Agency Name: Washington Commission in Integrated Pest Management

Notes: Assessing beneficial insects in planted refugia

WTFRC Collaborative Costs: none

Budget 1**Primary PI:** Dr. RT Curtiss**Organization Name:** Washington State University**Contract Administrator:** Office of Research Support and Administration**Telephone:** 509-335-9661**Contract administrator email address:** ORSO@wsu.edu**Station Manager/Supervisor:** Kimi Lucas (interim)**Station manager/supervisor email address:** kimi.lucas@wsu.edu

Item	2024	2025
Salaries	\$32,619.00	\$33,924.00
Benefits	\$13,232.00	\$13,761.00
Wages		
Benefits		
RCA Room Rental		
Shipping		
Supplies	\$550.00	\$550.00
Travel	\$2,000.00	\$2,000.00
Plot Fees		
Miscellaneous		
Total	\$48,401.00	\$50,235.00

Footnotes:

¹Salary for PI Orpet = pay rate of \$7,260.42/month X 12 months X 10% FTE (salary originally budgeted for Orpet in 2025 will be used instead for an additional 5% FTE to Curtiss and 8.78% FTE to technical assistant); Salary for Co-PI Curtiss = pay rate of \$7,083.33/month X 12 months X 5% FTE; Salary for technical assistant = pay rate of \$3,900/month X 12 months X 42% FTE. All personnel have a 4% COLA increase for year 2.

²Benefits rates of 32.8% (Orpet), 32.2% (Curtiss), and 42% (technical assistant)

³Natural enemy sampling supplies (sticky cards, plastic bags)

⁶Travel to field sites, approximately 100 miles a week for 25 weeks/year

Completed Objectives

1. Quantify natural enemy and plant communities in refugia plantings with weekly sampling at sites in the Columbia Basin across three growing seasons.
2. Assess spillover of natural enemies and effects on pests from the wildflower plantings by sampling in transects starting in the apple orchard edge row and extending up to 1,000 ft into the orchard.
3. Create a codling moth parasitoids reference collection housed at WSU-TFREC, to document and assist with identifications in Objective 2.
4. Share findings, including practical advice on economics of plantings relative to biocontrol benefits.

Significant Findings

- Refugia supported high numbers of beneficial insects, including syrphid flies (whose larvae are aphid predators) and bigeyed bugs (*Geocoris*; generalist predators). More of these taxa were found in refugia than in apple orchards. In the first year of study, abundance of these beneficials within apple orchards was not correlated with proximity to refugia.
- Refugia supported lower numbers of the omnivorous apple pest *Campylomma* than apple orchards, suggesting that the refugia will not induce *Campylomma* problems.
- Green lacewings and mite-eating ladybugs were scarcely found in refugia, and similar numbers of aphid-eating ladybugs were found in orchards as refugia. However, in-field observations suggest that the sampling method used (yellow sticky cards with no lures) may be ineffective for monitoring aphid-eating ladybugs. Inferring sources and spillover of highly mobile insects like green lacewing adults is difficult with the study design.
- Abundance of woolly apple aphids and leaves rolled by leafrollers within apple orchards was not correlated with proximity to refugia plantings.
- Codling moth parasitoids were extremely rare in collections from several Washington locations.

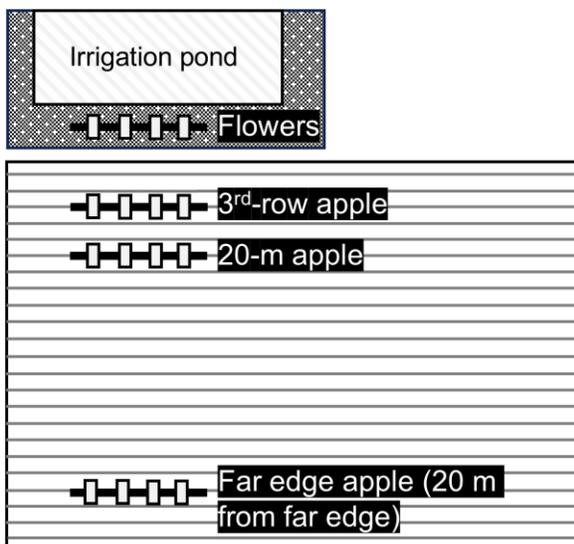
Methods

Objective 1. – Quantify natural enemy and plant communities in refugia

Monitoring for beneficial insects was conducted in flower plantings and at varying distances into adjacent apple orchards. Flowers were previously planted by orchardists and have been studied for pollinator diversity since 2022 in association with the WSDA Specialty Crop Block Grant-funded project entitled “Ensuring reliable pollination for Washington apples with cultural practices and conservation” led by the original PI Orpet; this project was subsequently led by PI Curtiss for the 2024 and 2025 seasons. This project, funded by Washington Tree Fruit Research Commission, supported staff to examine stored sticky cards from 2023 and quantify biocontrol agents and deploy new sampling in 2024 and 2025.

Field procedures varied between years. In 2023, six sites were studied. In 2024 and 2025, five of those were studied; one was excluded because the orchard was cut down. In all years, insects were monitored at each site in a flower planting plot and in three plots in the adjacent apple orchard (Figure 1). In 2023, the three orchard plots were: three rows in from the flowers, 20 meters in from the flowers (about 6 rows), and 20 meters from the opposite end of the orchard (Figure 1A). The plots were modified in 2024/5, replacing the far edge plot with an orchard-central plot that was 50–100 meters from the flowers, depending on the size of the orchard (Figure 1B). In all years, all plots were 20 m long. The flower plots were 0.3–1.0 m wide, and orchard plots were the width of one drive row.

A. Design 2023



B. Design 2024

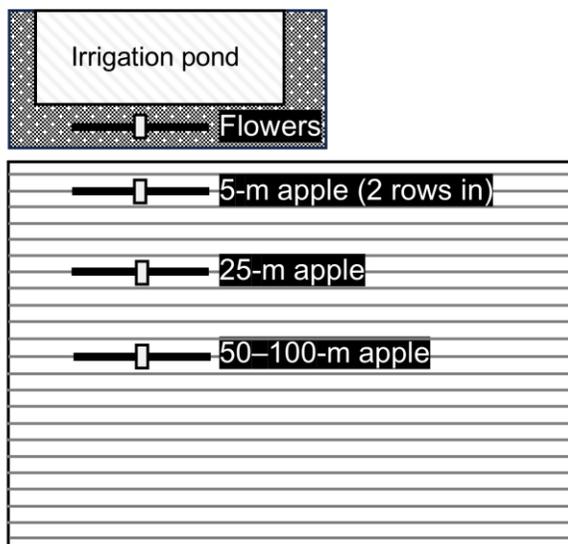


Figure 1. Diagram of sampling design used in 2023 (A) and 2024/2025 (B). An example is given where flowers were planted around an irrigation pond. Other plantings could be strips by roadsides or fields next to orchards. Orchard dimensions and row spacing varied between sites.

In 2023, four sticky cards were placed in each plot, and in 2024/2025 only one card was placed in each plot. Cards were replaced once every two weeks after bloom until fall. The card dimensions were 8×5 inches or 4×6 inches.

In all years, two blue vane traps, which are effective for collecting Hymenoptera (including parasitoids), were deployed 3 m from the ground in each plot for one 24-h interval every two weeks.

In all years, a survey of flowering plants was made on each visit by walking through each plot and recording all species in bloom.

Objective 2. – Quantify spillover of beneficials and monitor pests in orchard transects

Additional pest sampling was done in the orchard plots beyond the sticky card and blue vane trap sampling described in Objective 1 in refugia and orchards. Ten first-year shoots in each orchard plot were inspected on each visit. For green apple aphids, apple grain aphids, and rosy apple aphids, the number of infested leaves were counted. For woolly apple aphids, the number of infested leaf axils was recorded. For leafrollers, the number of rolled leaves was recorded.

Objective 3. – Create a codling moth parasitoid reference collection

Investigator RT Curtiss collected a small number of Hymenopterans that emerged from field-collected laboratory codling moth colonies. It was planned to request reference insects from the Washington State University insect museum to build a collection of known codling moth parasitoids to compare new specimens with. However, so few were collected from WA codling moths that they are currently an insignificant part of the biodiversity. Likewise, none were collected by other methods.

Objective 4. – Share findings.

Outputs of this project included lists of beneficial insect and plant species found in refugia plantings, quantification of aphid and leafroller pests correlated with beneficial insect spillover into orchards, and a better understanding of codling moth parasitoid fauna. Findings were shared on a project website all about refugia plantings, at least one extension presentation each year of the project, and a field day showcasing an example planting in the second year.

Results and Discussion

Objective 1. – Quantify natural enemy and plant communities in refugia

Sticky card data showed beneficial insects were found in variable numbers in flower refugia. The woolly apple aphid parasitoid *Aphelinus mali* was scarcely found in refugia plots relative to orchard plots in any year (Figure 2A, B, C). Syrphid flies appeared to make great use the refugia (Figure 2D, E, F), but green lacewings did not (Figure 2G, H, I). Bigeye bugs (*Geocoris*) were consistently most abundant in refugia, but scarcely found in orchards (Figure 3A, B, C). The opposite was true of the small black ladybugs that eat mites (Figure 3D, E, F), whereas similar numbers of aphid-eating ladybugs (i.e., two-spotted ladybugs, transverse ladybugs, convergent ladybugs) were found in refugia as orchards (Figure 2G, H, I). Distribution of mite and aphid lady bugs between plots varied greatly between years, with aphid lady bugs seeming to prefer refugia to orchards in 2024 and 2025.

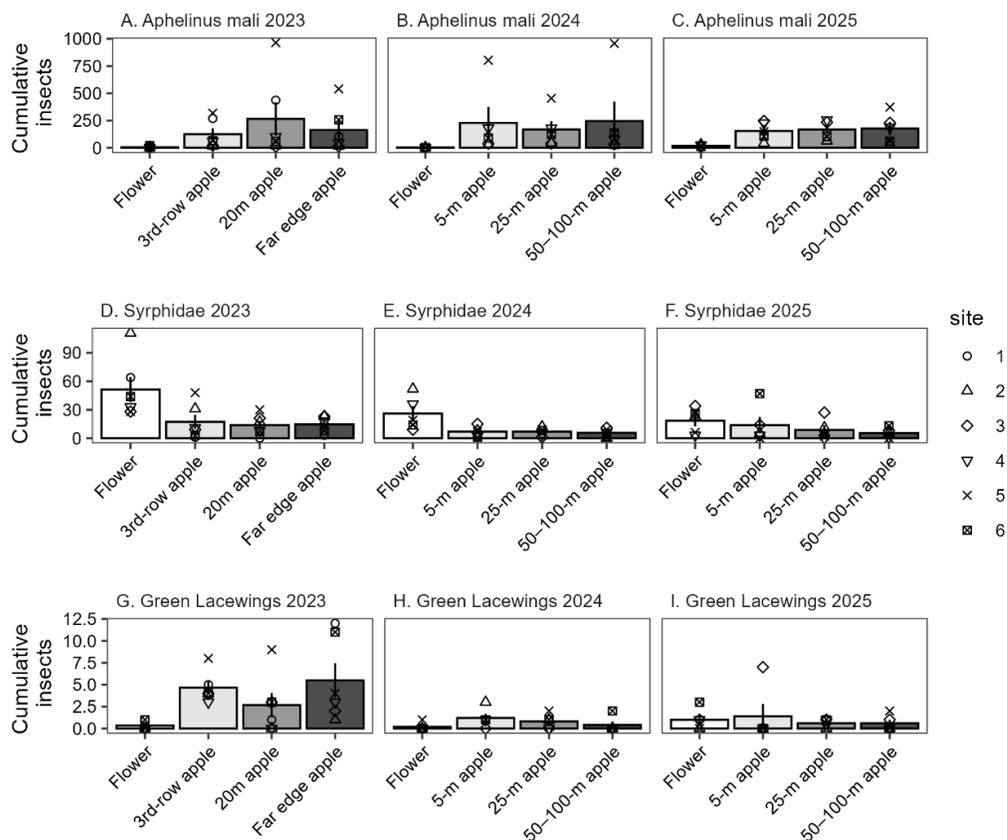


Figure 2. Cumulative number of beneficial insects found on sticky cards during 2023 at six sites, and 2024 and 2025 at five. Individual points show data for one site, and bars show the mean of all sites visited with standard error bars.

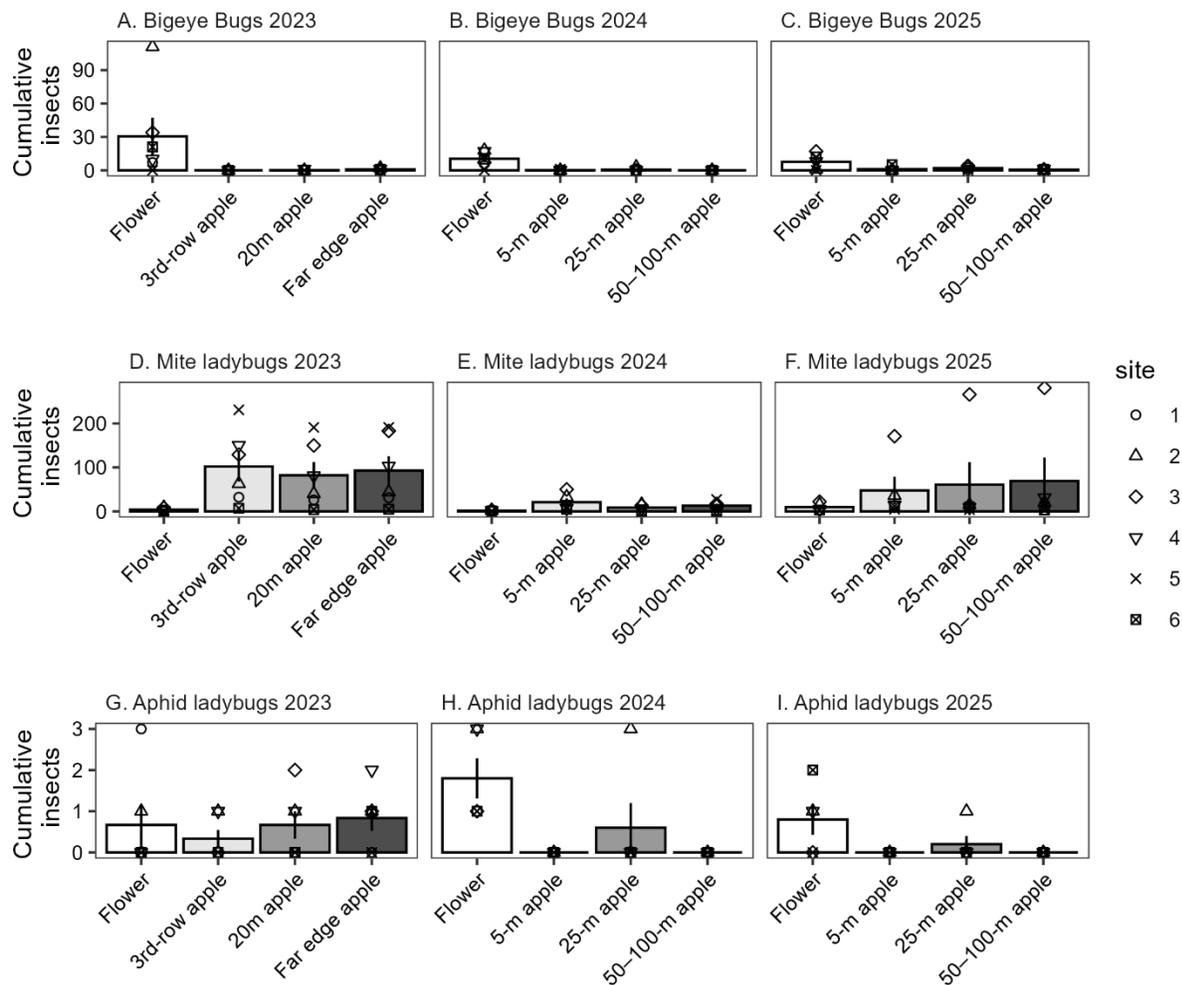


Figure 3. Cumulative number of beneficial insects found on sticky cards during 2023 at six sites, and 2024 and 2025 at five. Individual points show data for one site, and bars show the mean of all sites visited with standard error bars.

Monitoring showed that refugia likely improves the stability of syrphid and predatory bug populations. Adult syrphids eat nectar from flowers. Orchards had few flowers and low flower diversity (Figure 4), so they supported a smaller syrphid community than would be possible if season-long flowers were available, like in refugia plantings. Bigeye bugs were surprisingly more abundant in refugia than orchards. These predatory bugs are known to attack aphids in orchards, indicating importance of refugia for their conservation and use in integrated pest management.



Figure 4. Flowering period of each species observed across sites and years in wildflower refugia and all orchard plots combined, arranged by earliest detection in wildflower refugia.

Some beneficial insects seemed indifferent to the planted refugia. For example, *Aphelinus mali* are specialists of woolly apple aphid, so it is not surprising that few were found in refugia. The same may be true of the small black ladybugs that eat mites; perhaps few mites occur in the refugia. On the other hand, green lacewings are highly mobile generalists and were expected to occur in refugia, but they were rarely observed compared with orchards. Similarly, there were about as many aphid-eating ladybugs in refugia as orchards. Sampling methods for lacewings and ladybugs may have been inadequate to capture their presence in the refugia. Likewise, the sticky card method may be ineffective for monitoring some taxa like aphid-eating ladybugs. In past studies, many ladybugs and ladybeetle larvae were observed in some refugia in some years, particularly on yarrow plants, which may host alternative prey for the ladybugs.

The blue vane traps that were deployed are highly effective at collecting pollinators and other Hymenoptera.

Objective 2. – Quantify spillover of beneficials and monitor pests in orchard transects

Woolly apple aphids (Figures 5A, B, C) and rolled leaves (Figures 5D, E, F) in apple orchards were found in similar abundance regardless of distance from refugia in all years of this study.

Campylomma bugs from sticky cards were also found in similar abundance regardless of distance from refugia (Figure 5G, H, I). Many fewer *Campylomma* were found on sticky cards in the refugia than in orchards, suggesting that refugia are probably not sources of this apple pest.

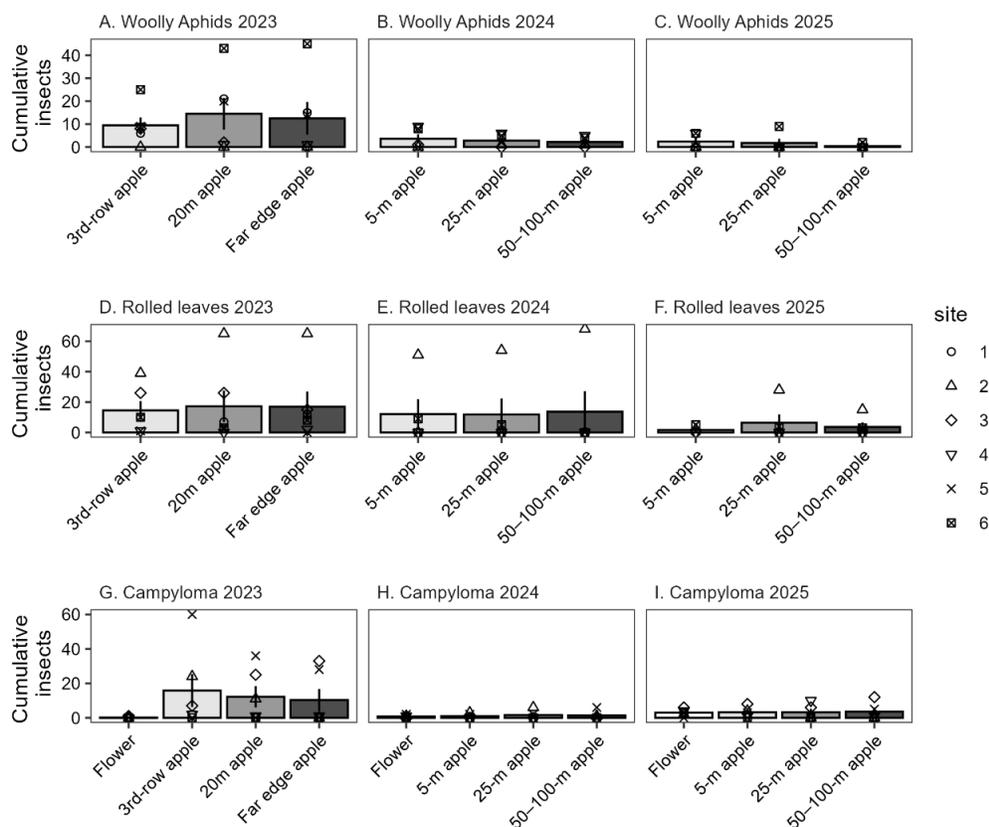


Figure 5. Cumulative number of pest insects found with apple tree sampling (panels A, B, C, D, E, F) or sticky cards (panels G-I) during 2023 at six sites and 2024 and 2025 at five. Individual points show data for one site, and bars show the mean of all sites visited with standard error bars.

Likewise, two of the leafhopper vectors of cherry X-disease, *Colladonus montanus reductus* and *Colladonus geminatus*, were uncommon in refugia relative to orchards (Figure 6). A third vector species, *Euscelidius variegatus*, was more abundant in refugia. However, the abundance of *E. variegatus* was so low in orchards, including edges close to refugia, that it seems that the refugia probably were not a major source of X-disease to neighboring cherry orchards; evidence from movement studies in Oregon suggest *E. variegatus* is not very dispersive, which is consistent with our observations here.

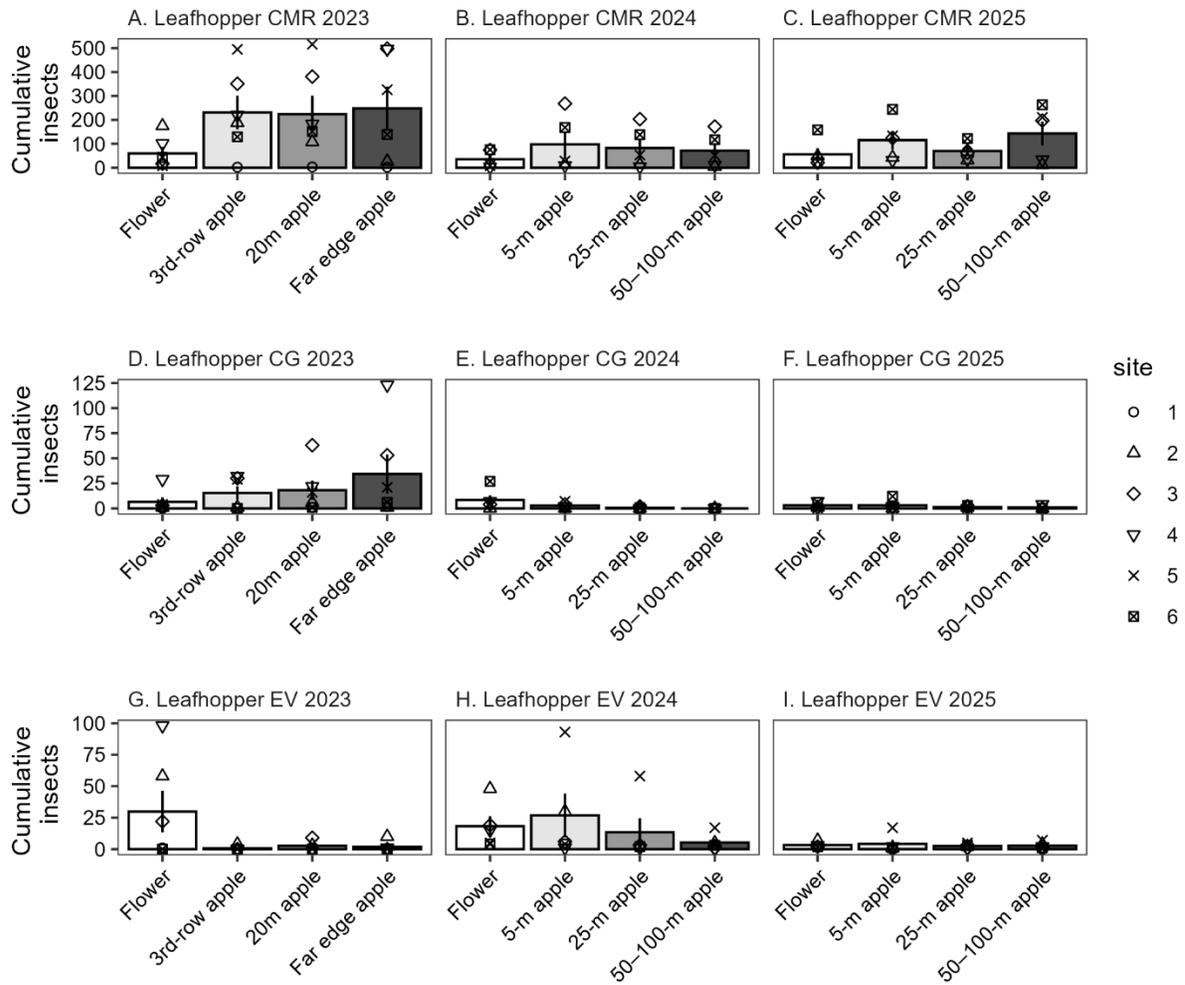


Figure 6. Cumulative number of leafhoppers *Colladonus montanus reductus* (CMR), *Colladonus geminatus* (CG), and *Euscelidius variegatus* (EV) found on sticky cards during 2023 at six sites and 2024 and 2025 at five. Individual points show data for one site, and bars show the mean of all sites visited with standard error bars.

Measuring the effect of refugia on crop areas has proven difficult. There was generally no clear pattern of insects spilling over from refugia into orchards. However, spillover is difficult to infer with the study design. We expected to find more of some insects in orchard plots closer to refugia, with clear declines in abundance as distance from refugia increased. However, if insect dispersal is great and is highly influenced by orchard-specific factors like prey density, patterns may not be clear. A relatively small number of refugia-generated insects may colonize orchards each spring and cause a subsequent numerical response to high prey density. This may result in more beneficial insects

observed in the orchard (where there is food, e.g., woolly apple aphids) than in the refugia despite the early importance of refugia as an initial source population of predators.

Despite the limitations of the study, it seems reasonable to suggest that the refugia studied are less important for specialized insects that feed on apple pests because their prey will always be higher in the orchard. This is the case for the woolly apple aphid specialist *A. mali*. However, if refugia contained firethorn (none of the studied refugia had this plant), which is a plant that woolly apple aphids can feed on, then refugia may have been a source of *A. mali*. Generalists that require flowers during the adult stage and are highly mobile, e.g., syrphid flies, likely benefit from refugia.

Likewise, the direct effect of refugia on pests is also difficult to infer. Rosy apple aphids were less common than other pests (Figure 7). Similarly, very few green apple aphids (27 insects total), and apple grain aphids (12 insects total) were found in the orchards we monitored.

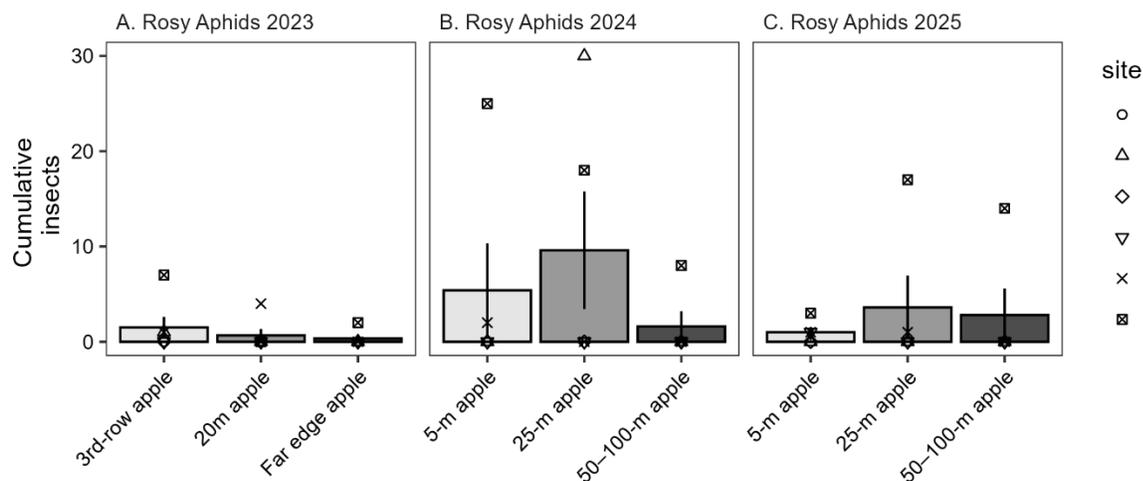


Figure 7. Cumulative number of rosy apple aphids found with apple tree sampling during 2023 at six sites and 2024 and 2025 at five. Individual points show data for one site, and bars show the mean of all sites visited with standard error bars.

Objective 3. – Create a codling moth parasitoid reference collection

Parasitoids in field-collected codling moth colonies were collected each year in extremely small numbers. Identification and creation of a reference collection is ongoing. However, their rareness in collections suggests that they are an insignificant component of codling moth management. In contrast, fungal pathogens have been found in codling moths far more frequently than parasitoids, suggesting that they may eventually be useful as management tools.

Objective 4. – Share findings.

Development of educational materials to share is ongoing. Investigator M Luppino established a project website (<https://cahnrs.wsu.edu/tfrec-orpet/insect-habitat-survey/>) that included photos of flower plots and insects found. Luppino spoke about the project at ten events, including at NCW Apple Day in 2025, the 2025 WA Hort EXPO, reaching more than 600 individuals directly across the three years of the project. Field days with orchard manager cooperators were held at one of the flower plantings each year.

Conclusion

The results indicate that refugia are heavily used by syrphid flies, which are important aphid predators. There was not clear evidence that other beneficial taxa were utilizing refugia en masse or spilling over into neighboring orchards. The same is true of pests; there was no evidence that these refugia are pest sources or contribute to pest outbreaks. However, pollinators greatly benefitted from these refugia, and there were significant positive effects to their populations.

All objectives were completed by the end of 2025. Three years of insect sampling were conducted, and samples were quantified. Technical staff are now trained for sampling procedures and for identification of beneficial insects on sticky cards for future projects. Findings are in the process of being published in peer reviewed journals as of the writing of this report. The previous lead investigator, Orpet, left Washington State University to Oregon State University January 1, 2025, so the lead role was passed to RT Curtiss for the final year of the project. Curtiss oversaw project administration. Sampling and insect quantification was managed by Luppino, who filled this role in previous years. Orpet stayed as a co-PI to assist with administration and data analysis.