# **Project Title:** Tactics to improve natural enemy releases in tree fruit

**Report Type:** Final Project Report

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**Cooperators**: Steve Arthurs (BioBee); Chuck Weaver (G.S. Long & Parabug); Rudy Prey; Justin Ellgen (Simplot) [note: apple grower cooperators are specified in apple report]

**Project Duration:** 2 Year

**Total Project Request for Year 1 Funding:** $102,558*
**Total Project Request for Year 2 Funding:** $106,033*
*50% by WTFRC Apple Crop Protection, 50% by FPC/PPC Pear

**Other related/associated funding sources:**
**Awarded**

| | |
|---|---|
| **Funding Duration:** | 2020-2023 |
| **Amount:** | $36,614 |
| **Agency Name:** | BioBee |
| **Notes:** | In-kind match of commercial insectary insects, Artemia (brine shrimp cysts on tape), and shipping costs for beneficials to be used in this project. Itemized estimate provided by BioBee. |

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| **Funding Duration:** | 2020-2023 |
| **Amount:** | $720 |
| **Agency Name:** | Parabug, Chuck Weaver private contractor |
| **Notes:** | In-kind match of drone pilot labor for releasing insects as part of Obj. 2. ~$18/acre × 10 drone-treated acres per trial × 2 trials (apple & pear) × 2 years. |

| | |
|---|---|
| **Funding Duration:** | 2021-2022 |
| **Amount:** | $29,968 |
| **Agency Name:** | Western IPM Center, project initiation grant |
| **Notes:** | This project expanded the efforts in this grant by providing support to conduct grower input sessions and a needs assessment survey. The WIPMC grant was also used to start a grant team and stakeholder |

advisory group that submitted the WSARE grant (below).

**Funding Duration:** 2020-2023
**Amount:** $348,733
**Agency Name:** Western SARE
**Notes:** This was a complementary (non-overlapping) project, specifically focusing on earwig releases in apple and pear, on the ground and by drone.

**Requested**
**Funding Duration:** June 2024 – May 2027
**Amount:** $350,000
**Agency Name:** Western Sustainable Agriculture Research and Education (WSARE)
**Notes:** This project proposal used the data gathered from "Tactics to improve natural enemy releases in tree fruit" to develop targeted questions that will allow for the creation of best management practices for lacewing releases in apples.

**Funding Duration:** June 2024 – May 2027
**Amount:** $81,139
**Agency Name:** Washington Tree Fruit Research Commission (ACP)
**Notes:** The WSARE proposal above includes funding for one lead technician's salary and extension activities. Due to budget limitations, we were unable to request salary for additional research support. Therefore, this funding request is for an assistant for the lead technician so that the research can be completed. We will be informed of the funding decision in March.

**Funding Duration:** 2024-2026
**Amount:** >$15,000
**Agency Name:** BioBee
**Notes:** In-kind match for the above WSARE project; commercial insectary lacewings (Awarded: will receive if the above is funded)

**Funding Duration:** 2024-2026
**Amount:** ~$7,500
**Agency Name:** Zirkle Fruit
**Notes:** In-kind match for the above WSARE project; commercial insectary lacewings and drone pilot labor/fees (Awarded: will receive if the above is funded)

**Funding Duration:** June 2024 – May 2027
**Amount:** $109,581
**Agency Name:** Washington Tree Fruit Research Commission (ACP) & Fresh and Processed Pear Committee Research
**Notes:** New funding request to pursue research on whirligig mite releases and conservation. In addition to unrelated work in potatoes, this proposal was brought about by results from Obj. 1 of this project and other projects in pears.

**WTFRC Collaborative Costs:** None

**Budget 1***

**Organization Name:** USDA-ARS **Contract Administrator:** Mara Guttman
**Telephone:** 510-559-5619 **Email address:** mara.guttman@usda.gov
**Station Manager/Supervisor:** Rodney Cooper **Email Address:** rodney.cooper@usda.gov

| Item | 2021 | 2022 |
|---|---|---|
| **Salaries**[1,4] | $17,458 | $17,894 |
| **Benefits**[1,4] | $5,587 | $5,726 |
| **Wages** | $0 | $0 |
| **Benefits** | $0 | $0 |
| **Equipment** | $0 | $0 |
| **Supplies**[2] | $6,500 | $6,500 |
| **Travel**[3] | $0 | $0 |
| **Miscellaneous** | $0 | $0 |
| **Plot Fees** | $0 | $0 |
| **Total** | **$29,545** | **$30,120** |

**Footnotes:**
[1]GS-5 technician for 6 months per year, 100% FTE at 32% benefits, Year 2 includes 2.5% COLA increase. Technician would assist WSU postdoc (see below) with sampling in all locations. This technician will also assist the postdoc with surface sterilization and PCR for gut content analysis.
[2]Funds to purchase PCR reagents and other PCR supplies for gut content analysis, trapping supplies, and some commercial nutritional supplement products (others provided as in-kind match).
[3]Fuel to field sites will be provided by USDA base funds and is not requested.
*50% by WTFRC Apple Crop Protection, 50% by FPC/PPC Pear
[4]This funding (both years) has been deobligated by USDA-ARS and WTFRC has made it available for WSU, to partially support a graduate student who is assisting with this project

**Budget 2***
**Organization Name:** WSU
**Contract Administrator:** Stacy Mondy
**Contract administrator email address:** anastasia.mondy@wsu.edu
**Station Manager/Supervisor:** Chad Kruger **Email Address:** cekruger@wsu.edu

| Item | 2021 | 2022 |
|---|---|---|
| **Salaries**[1] | $52,827 | $54,940 |
| **Benefits**[2] | $18,373 | $19,108 |
| **Wages**[3] | $1,200 | $1,248 |
| **Benefits**[3] | $113 | $117 |
| **Equipment** | $0 | $0 |
| **Supplies** | $500 | $500 |
| **Travel** | $0 | $0 |
| **Miscellaneous** | $0 | $0 |
| **Plot Fees** | $0 | $0 |
| **Total** | **$73,013** | **$75,913** |

**Footnotes:**
[1]Nottingham salary ($7,612.50/mo × 12 mo × 2% FTE = $1,827 Year 1, Year 2 reflects 4% COLA increase) + Postdoc salary ($4,250/mo × 12 mo × 100% FTE = $51,000 Year 1, Year 2 reflects 4% COLA increase). Nottingham to supervise data collection efforts in pear in the Wenatchee area and advise on project methods and data summary. WSU Postdoc will be based at the USDA-ARS facility in Wapato, WA and supervised by Schmidt-Jeffris. The postdoc will be responsible for leading data collection and summarizing project results. Due to difficulties in finding a qualified postdoc candidate, we have expanded our search to also include an associate in research, which would have a similar salary, but be hired at the M.S. level. The associate in research (Daniel Hausler) was hired in early 2022.
[2] Benefits rate for Nottingham is 29.9% ($547 Yr 1, $569 Yr 2). Benefits rate for postdoc is 35% ($17,826 Yr1, $18,539 Yr2).
[3]Summer technician at $15/hr×8 hr/wk ×10 wks, 9.4% benefits rate, salary includes 4% COLA increase in Year 2
*50% by WTFRC Apple Crop Protection, 50% by FPC/PPC Pear

**Note:** This report primarily contains pear-related content. Apple results are presented in detail in the Apple Crop Protection report.

## OBJECTIVES

**Obj. 1. Improve retention of released natural enemies.** We tested whether commercially available food supplements (Artemia cysts on tape, *Ephestia* eggs on cards) and lures (methyl salicylate) increased retention of released natural enemies and also examined whether they recruited resident natural enemies and decreased pest populations. Only Artemia cysts were used in 2023 (*Ephestia* eggs were dropped). All fieldwork and pest/natural enemy counts are completed and analyzed for this project, but the molecular work is not yet complete. Several factors caused significant delays, including a move to a new lab space (which needed repairs before use) and the need to change our gut content protocols; we determined that neither pear psylla nor orchard aphid pests amplify well with COI universal primers. To overcome this, a colleague (B. Ohler) designed a pear psylla primer and we adapted aphid primers from another lab – these must be run as a separate PCR from the COI primers, increasing the number of samples we are running. Finally, the need to identify lacewings using molecular techniques (see below) added many additional samples to our workflow. The molecular work will be completed before the project term date (June 2024).

**Obj. 2. Determine cost-effectiveness and efficacy of natural enemy release by drone.** In 2022, this we tested releases of *Orius insidiosus* and lacewings (*C. plorabunda*) by ground and drone. We determined that the 0.25-acre plot trials were not an adequate method for testing drone releases and instead focused entirely on various ground-based releases in 2023. An objective specifically testing lacewing releases by drone at a large scale was included in the proposed WSARE project (see other/related funding sources). This grant will help determine if drones are a viable tactic for releasing natural enemies in orchards more generally (not just lacewings in apples).

## SIGNIFICANT FINDINGS

**Releases of insectary natural enemies for pear psylla control** did not show any potential in this study. Recovery of released natural enemies was generally lower in the pear trials than in apple trials and the releases did not decrease pear psylla abundance. These results have allowed us to confidently advise growers to not use either *O. insidiosus* or lacewing releases for pear psylla control. Since we began these trials, a new natural enemy, the whirligig mite ("Crazee mite"), has become commercially available. Preliminary work conducted by colleagues indicates that it has strong potential for pear psylla control. Additionally, we informed the insectary industry that it does not appear that currently available natural enemies (with the potential exception of the new "Crazee mite") are not effective for pear psylla. As a result of consultations, one insectary is currently exploring their ability to rear a pear psylla natural enemy (details forthcoming, currently confidential).

**Tactics for retaining and recruiting natural enemies** had highly variable results between sites and years. In general, methyl salicylate lures showed some promise for recruiting lacewings (in apples only), *Campylomma*, and *Stethorus*. Food supplements may have increased *O. insidiosus* retention.

**Lacewing identification** became a critical component of this project. We determined that the "*Chrysoperla carnea*" we purchased for trials in 2021 were actually *C. externa* (purchased as larvae) and *C. plorabunda* (purchased as eggs). *Chrysoperla externa* can be separated from other lacewings visually under magnification, but to distinguish between "resident" lacewings and the released *C. plorabunda*, we had to develop molecular methods. We determined that the COI gene, which we are using in our gut content analysis, can also be used to separate resident from released lacewings. It is important to note that the lacewing species present in orchards that is often referred to as "*C. plorabunda*" is likely *C. johnsoni* and therefore a different species that what is commercially

available. However, *C. plorabunda* is native to Washington (found outside of orchards) and therefore likely to be a better climate match that *C. rufilabris*.

***Orius insidiosus* releases** were performed as part of the retention experiments for aphid and pear psylla control, but data from these trials also allowed us to access the efficacy of this predator for thrips control. One release of *O. insidious* (2,000/acre) reduced adult thrips on sticky cards by 50% in both apple trials and by >50% in one of the pear trials. Evaluations of thrips damage did not occur as part of this work, but should be included in future studies. More frequent releases (at lower rates) may be more effective and economical.

**Whirligig mite** was found in abundance on beat trays in some of our study locations. The role of this predator in North American orchards has received little attention, but research from Ireland and preliminary work from other projects suggest that it may be an important orchard natural enemy. It recently became available for purchase in the U.S. (Oregon only).

**Grower survey and discussion, 2021-2022**. Leveraged funding from the Western IPM Center allowed us to conduct a grower survey and a series of listening sessions (in collaboration with Tianna DuPont and Ashley Thompson). 132 growers and consultants responded, representing 43,868 apple and pear acres. 37 respondents (28%) are using biocontrol releases occasionally or annually on 7,842 acres costing them $153 per acre on average. The main natural enemies they are releasing are lacewings (29%), lady beetles (28%), and predatory mites (25%). The main barrier to adoption of releases was lack of knowledge/recommendations on how to release successfully (52%). Five stakeholder input sessions were conducted in 2021-2022 in Omak, Wenatchee, Yakima, Hood River, and Medford with a total of 60 participants. The input sessions identified the following as critical research areas: (1) information to make natural enemy releases more effective/useful, (2) evidence of efficacy, (3) what species to release, (4) where to purchase, (5) release timings, (6) release rates, (7) a list of common release mistakes and how to avoid them, (8) on farm success stories, (9) consistent supply, (10) proper placement in the tree/orchard, and (11) pesticide toxicity to natural enemies. Information from the survey and sessions was used to support the pending WSARE grant application to expand the work on lacewings.

## RESULTS AND DISCUSSION

### Obj. 1. Improve retention of released natural enemies

The study was conducted two commercial pear orchards (organic: Leavenworth, WA in 2022 and soft conventional: Wapato, WA in 2023). The organic orchard in 2022 had a relatively low pear psylla population, so we switched locations in 2023 to better assess differences between treatments. In 2022, releases were conducted on June 3rd and monitored for three weeks post-release. In 2023, releases were conducted on May 25th and monitored for four weeks post-release.

There were five treatments consisting of combinations of lure use (Predalure, methyl salicylate), food supplements (Artemia, brine shrimp cysts on tape Fig. 1 + *Ephestia* eggs on cards), and releases (100,000 "*C. carnea*" lacewing eggs + 2,000 *Orius insidiosus* per acre): (1) Predalure + Foods + Release, (2) Predalure + Release, (3) Food + Release, (4) Release only, and (5) No-release control. In 2022, the "Food" treatment only used Artemia tape (the *Ephestia* eggs were dropped). Rates for the food treatments and lures were: 1 lure/plot, 50 m Artemia tape/plot, and 35,000 *Ephestia* eggs/plot (1 card/30 tags). Each combination was replicated in


**Fig. 1.** Ladybeetle feeding on Artemia tape

the orchard 5 times in 0.25-acre plots. Pear psylla, mites, lacewings, and minute pirate bugs were counted prior to release and then once weekly after release. Pear psylla and mites were sampled by collecting a 30-leaf brush sample in each plot. Beat tray samples were collected from the 9 center trees of each plot and all natural enemies from the tap counts were collected and stored in ethanol for identification and use in molecular gut content analysis. Two sticky cards were also hung in each plot to monitor adult natural enemies. The "*C. carnea*" sold by the insectary were tentatively identified as *C. plorabunda*. Final determination of the lacewing species using song analysis will be done by a lacewing biologist (K. Taylor, University of Maryland) this spring.

In the six trials (2 commercial apple, 2 research apple, 2 pear), only 8 *O. insidious* were recovered. However, the consistent decrease in thrips counts in plots where *O. insidiosus* were released indicates that this predator remained in plots long enough to reduce pest populations. Although it was most commonly found 1-2 weeks post-release, in the 2022 commercial apple and 2023 research apple orchards, *O. insidiosus* were found over a month after release. This species is not native to Washington and has never been found in an area where it was not recently released, therefore all recovered *O. insidiosus* are from that year's releases. Of the few *O. insidiosus* found, 75% of them were recovered from plots with supplementary foods. The two individuals recovered from plots without foods were found one month post-release, when the foods were likely completely consumed/decayed. Therefore, there is some evidence that the Artemia tape increased retention of *O. insidiosus* in the field. In future studies examining efficacy of *O. insidiosus* for thrips control in apples, the use of releases in combination with Artemia tape should be explored.

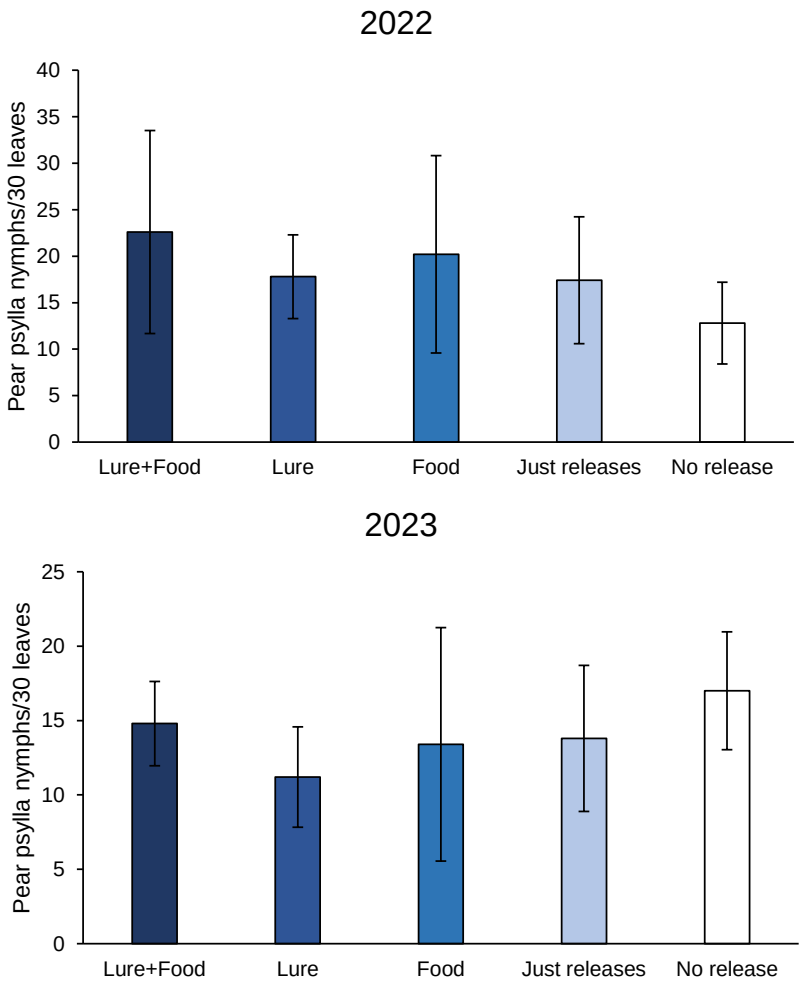


**Fig. 2.** The releases and the retention treatments did not improve pear psylla control. Seasonal sums.

Molecular identification of the *carnea*-group lac ewings recovered from the retention trials is ongoing. All samples have been processed and sequenced. Sequences have been aligned and we are currently constructing computationally-intensive phylogenetic trees to determine which collected individuals "match" the controls directly removed from insectary bottles. This analysis is anticipated to be completed in February 2024. Based on preliminary analysis, no

treatment increased retention of released lacewings. However, applications of methyl salicylate lures timed for approximately when released lacewings become adults (as opposed to during the release) may increase the likelihood that the adults remain in the orchard.

In 2022, None of the treatments in our study differed from each other in pear psylla abundance (Fig. 2); releases of *C. plorabunda* and *O. insidiosus* did not reduce pear psylla counts and lures and food supplements did not alter treatment efficacy. We were able to recover our released predators: two *O. insidiosus* were found one week post-release and two *C. carnea* larvae were found three weeks post-release. Releases significantly decreased thrips abundance (Fig. 3). This effect was also seen in some of the apple trials and indicates *O. insidiosus* releases should be further investigated for their potential to reduce thrips damage to susceptible fruit varieties.

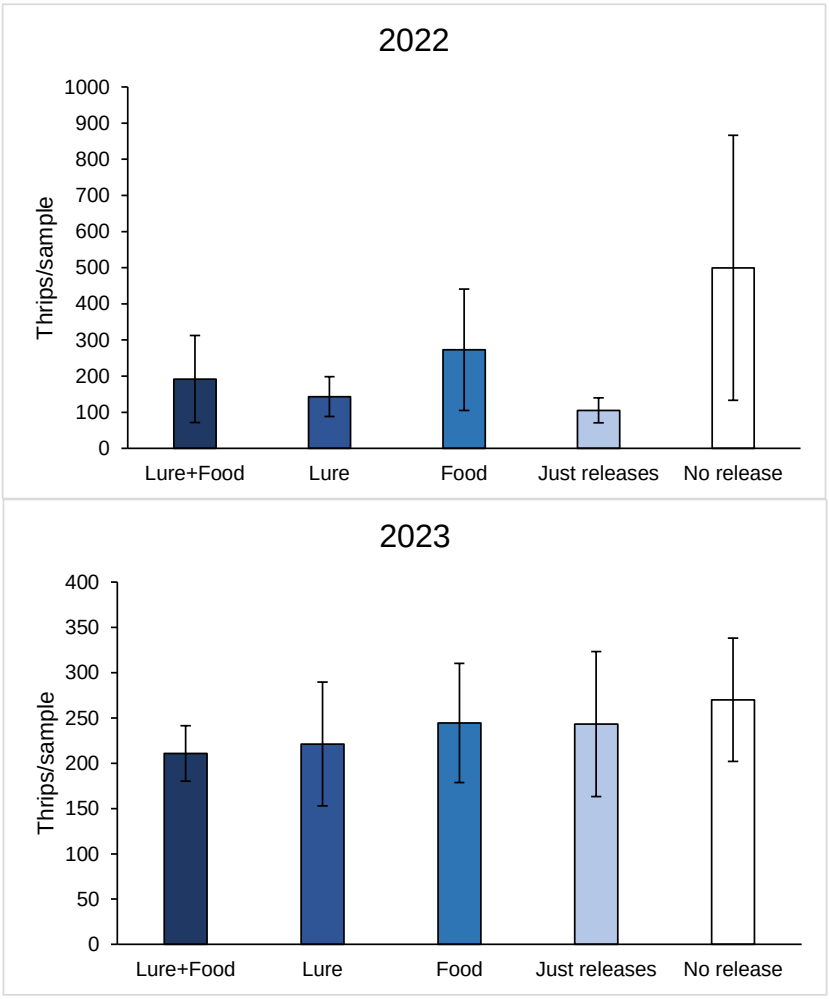


**Fig. 3.** In 2022, releases decreased thrips. This effect was not seen in 2023. Seasonal sums.

Lures increased *Campylomma* abundance (Fig. 4). Across our samples, the most prevalent natural enemies were *Campylomma*, whirligig mites, and spiders. *Deraeocoris* and lacewings were also present, but far less abundant.

In 2023, none of the treatments affected pear psylla abundance (Fig. 2). No *O. insidiosus* were found post-release and only one lacewing larvae was found. We also found lacewing larvae pre-release, so we are conducting genetic analysis to determine if the single recovered larvae is “released” or “resident”. Unlike the 2022 trial, releases did not decrease thrips abundance (Fig. 3). This may be because the *O. insidiosus* were not found post-release. The lure treatment was associated with an increase in *Campylomma*, but the trend was less dramatic in this trial compared to 2022 (Fig. 4). *Camplyomma* counts were also higher in the lure treatments in the 2023 apple trial. Unlike the 2022 trial, *Stethorus* were abundant in this orchard and we found that lures increased *Stethorus* abundance (Fig. 5). This effect was also observed in some of the apple trials. Methyl salicylate lures should be further investigated for their ability to increase *Stethorus* and *Campylomma* populations. We generally observed unusually high numbers of *Stethorus* throughout the season in a variety of crops in 2023; if *Stethorus* continues to be abundant, it may play a more important role in spider mite control in pears and other crops.

These samples are being used to conduct PCR-based gut content analysis to determine (1) which predators are most commonly found to have consumed pear psylla, (2) if any predators consumed the food supplements, and (3) if any pear psylla predators commonly eat each other (intraguild predation). This will provide growers with better recommendations on which natural enemies to focus on as part of conservation efforts. We are particularly excited to find whirligig mites in abundance; this is an important natural enemy of potato psyllids in weedy hosts near potato fields (Fig. 6). It is likely to also be an important pear psylla predator. Currently, whirligig mites are available for purchase in Canada and Oregon, but not Washington.

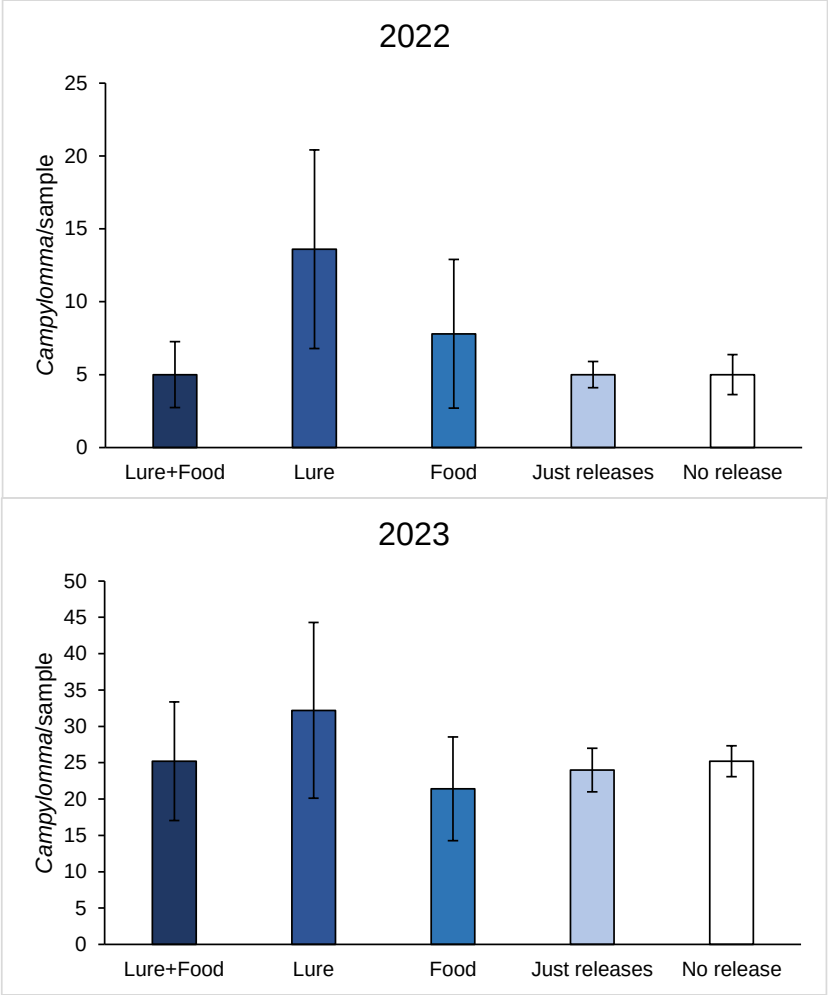


**Fig. 4.** In 2022, lures used alone significantly increased *Campylomma*. This effect was also seen in 2023, but was not statistically significant. Seasonal sums.

Between sites and across years, there was very little consistency in the effects of the treatments. Taken in combination with the apple data, *Stethorus* generally increased in plots with lures and may exert control on mites while rapidly moving between plots. Lacewings also showed a similar, although weak, trend. Because natural enemies interact with each other and pests over time, it is difficult to discern if changes in natural enemy abundance due to treatments are due to predation amongst themselves or changes in pest densities. The gut content work, which should be completed by June 2024, may provide additional information about these relationships.

**Obj. 2. Determine cost-effectiveness and efficacy of natural enemy release by drone**

In 2022, we tested releases of *C. plorabunda* eggs and *O. insidiosus* adults by ground (sprinkled) and by drone at a rate of 100,000 and 2,000 per acre, respectively. Because of the lack of observed effects on pear psylla in 2023 (and in the Obj. 1 trials), in 2022 we focused exclusively on the ground-based treatments. The trials were conducted in the same orchards each year as the Obj. 1 trials. In 2022, releases were conducted on June 10$^{th}$ and monitored for three weeks post-release. In 2023, releases were conducted on May 25$^{th}$ and monitored for four weeks post-release.

None of the treatments resulted in a decrease in pear psylla abundance in either year of the

study (Fig. 7). We were also unable to recover any of our released *O. insidiosus* and *C. plorabunda* in either year. A limited number of resident green lacewings were found in both trials. In 2022, due to time limitations, we were unable to release the natural enemies until a week after arrival (they were kept at 50 °F). It is possible that the quality of the natural enemies declined during storage, although we did confirm that they were alive prior to release. However, even in the retention trial and the 2023 efficacy trial, when natural enemies were immediately released, no effect was observed on pear psylla. Natural enemies that are currently commercially available are likely not appropriate for pear psylla management. However, the newly available "Crazee mite" shows potential for pear psylla control and should be investigated in future studies.

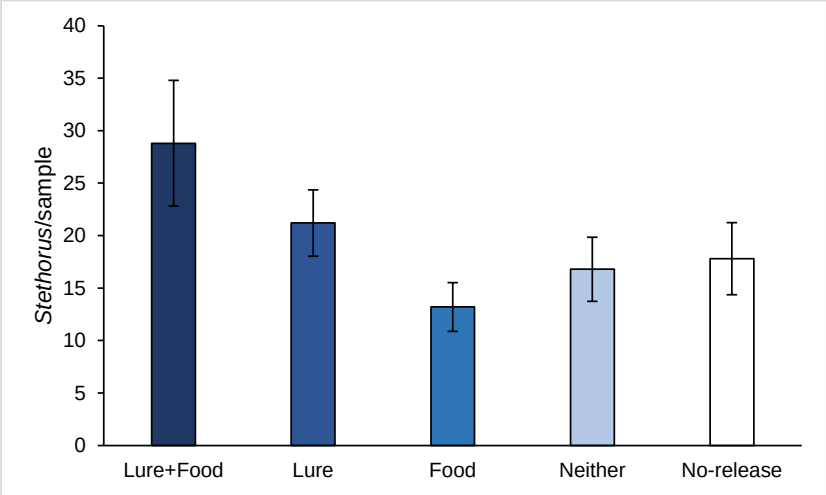


**Fig. 5.** In 2023, lures increased *Stethorus*. They were not present in the 2022 trial. Seasonal sums.

**Fig. 6.** Whirligig mite eating a pear psylla.

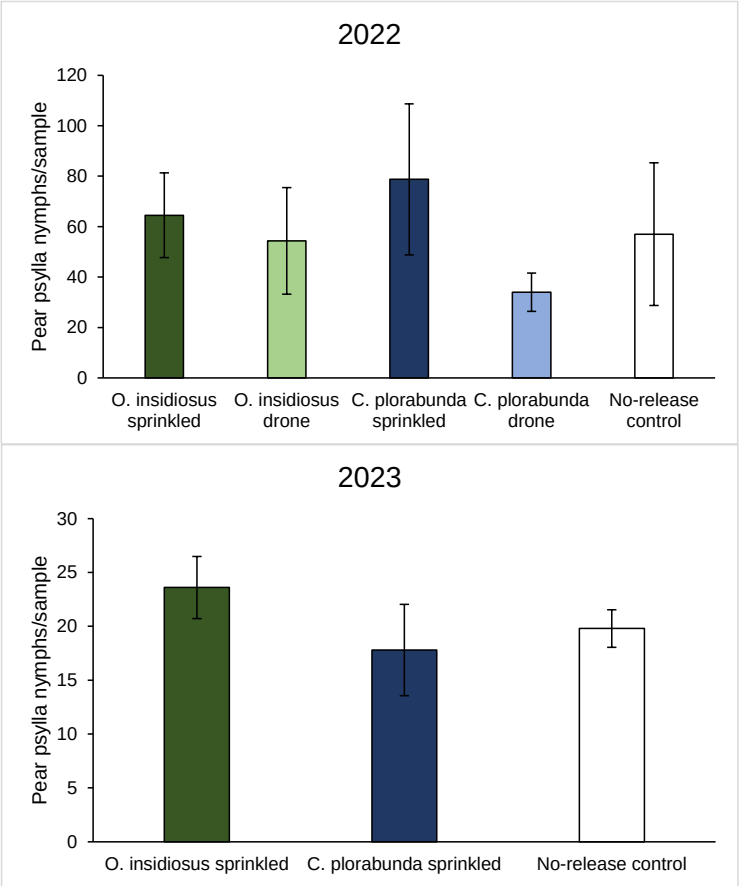


**Fig. 7.** In 2022 and 2023, releases of *O. insidiosus* or *C. plorabunda* did not affect pear psylla abundance. Seasonal sums.

## EXECUTIVE SUMMARY

**Project title:** Tactics to improve natural enemy releases in tree fruit

**Key words:** lacewing, *Chrysoperla plorabunda*, *Orius insidiosus*, lures, supplementary foods

**Abstract:**

Growers have experimented with releases of natural enemies to control pests in tree fruit, but there are currently no best practice recommendations for releases in orchards. The purpose of this project was to determine which natural enemies and release methods showed the most promise for controlling orchard pests, with the pear work focusing on pear psylla. We also examined the potential of lures and supplementary food products for recruiting resident natural enemies and retaining released natural enemies. Tactics for retaining and recruiting natural enemies had highly variable results between sites and years. In general, methyl salicylate lures showed some promise for recruiting lacewings in apples and *Stethorus* in apples and pears. There was also a slight trend for increases of *Camplyomma* in lure-based treatments. In 2023, *Stethorus* was unusually abundant throughout the season in many crops and the importance of this natural enemy in reducing pest mite abundance in pears may need to be re-evaluated. Food supplements may have increased retention of released *O. insidiosus* and subsequently reduced thrips abundance. The use of lures after a lacewing release should be investigated to determine if they encourage released lacewings to remain in the orchard after they develop into adults. None of the release treatments decreased pear psylla abundance and retention of the released natural enemies in pear trials was much lower in than in apple trials. Commercially available natural enemies appear to be unsuitable for pear psylla control. However, the whirligig mite became available for purchase in Oregon in 2023 and has shown promise in preliminary research. As new natural enemies enter the market, they should be evaluated for their ability to control pear psylla. Augmentation with commercially available natural enemies may be particularly helpful in pear orchards in transition to organic or IPM spray programs.