Biological Control in Pest Management Systems of Plants
ANNUAL REPORT OF CONTRIBUTING PROJECT TO
COOPERATIVE REGIONAL PROJECT W5185

January 2024 to December 2024

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3. PROGRESS OF WORK AND PRINCIPAL ACCOMPLISHMENTS:

Objective 1: Import and Establish Effective Natural Enemies

Objective 1a. Survey indigenous natural enemies.

1) Arthropod or weed pests

a) Degree to which objective has been accomplished:

Adams: Our lab is currently rearing and releasing *Trissolcus japonicus* against the invasive brown marmorated stink bug (*Halyomorpha halys*). We are also rearing and releasing three wasps against the invasive spotted wing drosophila (*Drosophila suzukii*), including *Ganaspis kimorum* (formerly *Ganaspis brasiliensis*), *Leptopilina japonica*, and *Pachycrepoideus vindemmiae*.

Dillman: Our lab is working to isolate and identify new species of entomopathogenic nematodes (EPNs). We have isolated a new species from Thailand, which we described this year. We are now, in collaboration, investigating its potential as a biocontrol agent against *Helicoverpa zea*.

Hoddle: Native egg parasitoids in the genus *Anastatus* (Hymenoptera: Eupelmidae) have been proactively screened for efficacy towards eggs of spotted lanternfly (*Lycorma delicatula*). Native parasitoids reared from eggs of native lantern flies in Arizona and a widely distributed native parasitoid, *A. reduvii*, have been assessed in quarantine at UC Riverside. Results indicated that at least one species of native parasitoid, *A. reduvii*, may have potential as a natural enemy of *L. delicatula*. However, the impacts of this parasitoid on *L. delicatula* eggs are dependent upon the species of host eggs on which this parasitoid was reared prior to exposure to *L. delicatula* eggs. Completed field work in commercial citrus orchards continues to indicate that larvae of native hover flies (Diptera: Syrphidae) are important predators of Asian citrus psyllids, *Diaphorina citri*. Impacts of these native predators can be enhanced when invasive Argentine ants are controlled and flowering crops like alyssum, are provided.

Heraty: We continue to follow up on the accidental introduction of *Orasema minutissima* to the island of Hawaii as a potential biological control agent against *Wasmannia auropunctata* (Hymenoptera: Formicidae). Our current efforts center on sequencing populations of the ants and parasitoids from different locations in Hawaii and islands in the Caribbean and south Florida. Our phylogeny of Chalcidoidea was completed in 2024 (Cruaud et al. 2024).

Lara: Progress has been made on multiple pest projects. Several thousand sentinel eggs of *H. halys* were deployed in Northern California during 2024 to monitor for resident parasitoids of this stinkbug pest. Several collections of gelechiid larvae were made to look natural enemies that may attack this group of moths as part of proactive biocontrol efforts targeting *Phthorimaea absoluta*. Also, funnel traps and prism traps were deployed across several California counties to monitor for resident natural enemies of buprestid beetles as part of proactive biocontrol efforts targeting *Agrilus planipennis.*

Moran: A leaf-feeding moth, *Condica viscosa*, was collected as a candidate agent for stinkwort (*Dittrichia graveolens*).

b) Incomplete work or areas needing further investigation:

Adams: Impact on target invasive species (*H. halys, D. suzukii*) will continue to be measured in the future.

Dillman: We are still testing a new entomopathogenic nematode species against insect pests and are working to identify and explore the potential of other strains and species. This work is ongoing.

Hoddle: The spotted lanternfly and Asian citrus psyllid projects detailed above in 1a have been completed and are currently being written up for publication.

Objective 1b. Conduct foreign exploration and ecological studies in native range of pest.

1) Arthropod or weed pests

a) Degree to which objective has been accomplished:

Andreas: We partner with CABI Switzerland to conduct flowering rush biocontrol and parrotfeather development. We also work with WSDA and BBCA in Italy to support biocontrol development for tree-of-heaven.

Borkent: Collections of *Psyllaephagus euphyllurae*, a key co-evolved parasitoid of the olive psylllid (*Euphyllura olivina*), were made in Europe (i.e., Spain and France) to support ongoing *P. euphyllurae* lab rearing and field release operations in California targeting *E. olivina*.

Hoddle: Foreign exploration was conducted in Valenca, Brazil, for a parasitic fly, *Billaea rhynchophorae*. Larvae of this fly parasitize pupae of the South American palm

weevil, *Rhynchophorus palmarum*, an invasive pest of palms in California. Parasitized weevil pupae were recovered in Valenca. Unfortunately, we were unable to keep the flies alive in the lab in Recife Brazil and adult flies did not mate or larviposit onto pre-pupal palm weevil larvae.

Moran: The stem-boring weevil*, Lixus carinerostris*, was imported into quarantine for host range testing as a candidate agent targeting crystalline ice plant, *Mesembryanthemum crystallinum.*
Park: A rapid identification of *Gastrophysa atrocyanea* (Coleoptera: Chrysomelidae), the potential biological control agent for invasive *Rumex* species, was developed using the UV-marking application. The application allows *G. strocyanea* to explore whole plants for oviposition, which is applicable for mass-rearing other biological control agents, including *Ceratapion basicorne*. The work was published in the Journal of Asia-Pacific Entomology.

b) Incomplete work or areas needing further investigation:

Hoddle: To be able to establish and maintain colonies of the parasitic flies that attack South American palm weevil, more work is needed on basic aspects of the behavior and biology of *B. rhynchophorae.*

Heraty: We continue to work with researchers in Argentina to revise species that are parasitoids of *Solenopsis* ants. Javier Torréns is working on a revision of the *Orasema susanae* species group. There are many different research areas in progress, especially on Aphelinidae, Eucharitidae and Mymaridae.

Objective 1c. Determine systematics and biogeography of pests and natural enemies.

1) Arthropod or weed pests

a) Degree to which objective has been accomplished:

Crowder: We created habitat suitability models for brown marmorated stink bug and two of its key natural enemies, *T. japonicus* and *Nosema maddoxi*. This work involved gathering data on both species through nationwide surveys. We then published a paper testing overlap between the species.

Hoddle: The systematics of lantern flies (Fulgoridae) in the genus *Scaralina,* native to Arizona, was completed. Numerous new species were described, and this work has been published in Zootaxa. Almost nothing was known about these native lantern flies until field, morphological, and molecular work was undertaken and completed. The reason this work was undertaken was to better prepare the southwestern US, and California in particular, for the anticipated invasion of spotted lantern fly, *L. delicatula*.

Heraty: We are developing a new research program on the genus *Encarsia*, which are aphelinid parasitoids of armored scales and whiteflies. The initial objectives are a revision of the *Encarsia*

strenua species group and a molecular phyogeny of the entire genus. This research was being conducted by a graduate student (Robert Kresslein).

Mc Donnell: Ongoing pest gastropod surveys in the western U.S. have shown that the wrinkled snail, *Xeroplexa intersecta*, has been introduced and is spreading in the Pacific Northwest. A guidebook on the slugs of California with an emphasis on introduced species was updated and translated into Spanish.

Park: With CABI-Switzerland, we evaluated the new natural enemy for invasive box tree moth (*Cydalima perspectalis*), which was found in South Korea. The parasitoid, *Braunsia hodorii* Kang, sp. nov., attacks the larvae of box tree moths. The work was published in the Journal of Hymenoptera Research.

b) Incomplete work or areas needing further investigation:

Heraty: Research is underway on developing a molecular phylogeny for the egg-parasitic Mymaridae by a relatively new graduate student (Krissy Dominguez). Her research is utilizing three different molecular approaches to look at congruence of results, and ultimately the proposal of a new classification for the group. We continue to develop a database for taxonomic and biological information on the superfamily in TaxonWorks. This system manages data for more than 30,000 taxonomic names and over 50,000 literature references, including information on their hosts and distributions.

Objective 1d. Determine environmental safety of exotic candidates prior to release.

1) Arthropod or weed pests

a) Degree to which objective has been accomplished:

Hoddle: The host range of natural enemies of spotted lanternfly, *L. delicatula*, were assessed in quarantine at UC Riverside. Previously completed work on *Anastatus orientalis*, an egg parasitoid native to China, the country of origin for *L. delicatula*, indicated that this parasitoid had a brought host range and posed unacceptable risk to native non-target US species. Additional work with a commercially available European species, *A. bifasciatus*, indicated that this parasitoid was also capable of parasitizing the eggs of a range of native US non-target species and should not be considered for use in a biological control program targeting *L. delicatula*.

Mc Donnell: Laboratory infectivity assays have demonstrated that the European malacopathogenic nematode, *Phasmarhabditis hermaphrodita* is lethal to *Monadenia fidelis*, a terrestrial gastropod species endemic to the Pacific Northwest.

Park: A nondestructive method was completed to examine the environmental safety of a potential biological control agent, *Mogulones borraginis*, for federally listed threatened and endangered plant species. During behavioral bioassays, the seed-feeding weevil preferred invasive houndstongue (*C. officinale*) to all native threatened and endangered plant species in Boraginaceae. The work was published in PeerJ.

b) Incomplete work or areas needing further investigation:

Hoddle: Findings of host range testing for *A. bifasciatus* are at an advanced stage of preparation and it is anticipated that this work will be submitted for publication in late 2024.

Objective 1e. Release, establish and redistribute natural enemies.

1) Arthropod or weed pests

a) Degree to which objective has been accomplished:

Adams: Our lab is measuring establishment of released parasitoids against brown marmorated stinkn bug in subsequent years post-release. We have recaptured T. japonicus at 80% of the release sites. ; Andreas: Released 12 biocontrol agent species (and strains) for nine weed species at over 200 field sites.

Borkent: In 2024, CDFA released *P. euphyllurae* for biological control of *E. olivina,* an invasive insect pest of olives. Additionally, two biocontrol agents were released for invasive weeds: *Aphalara itadori* against *Reynoutria sachalinensis* and *Aulacidea acroptilonica* against *Acroptilon repens*. Additionally, a survey of *Centaurea virgata* spp. *squarrosa* sites in Northern California, 10 years after the last release, found plants were heavily infested with *Sphenoptera jugoslavica, Bangasternus fausti*, and *Larinus minutus*. *Centaurea virgata* spp. *squarrosa* density had also decreased significantly from a monoculture to only a few individuals per site.

Lara: Several thousand *T. japonicus* parasitoids were released in Northern California during 2024 as part of biocontrol efforts targeting invasive *H. halys* populations.

Littlefield: Eleven releases of the gall mite, *Aceria drabae* for hoary cress (*Lepidium draba*), were made in Montana in the spring of 2024. Of these, mites were recovered at seven sites. Only a small proportion of the total stems inoculated produced galls. Gall material was also provided the Colorado Department of Agriculture Insectary in Palisades, and the University of Wyoming. As of 2024, releases have been made at 26 sites in Montana. Galls have been observed at approximately 70% of our releases, and its status of 19% of the releases is unknown (new 2024 releases). Only three sites are known to have failed, due to an herbicide application, heavy grazing, or perhaps due to site conditions (environmental factors).

Moran: The arundo armored scale, *Rhizaspidiotus donacis*, was demonstrated as established at eight field sites in the Sacramento and San Joaquin River watersheds of northern California.

Ramirez: We identified field release sites in New Mexico for *A. drabae*, a gall mite used for classical biocontrol of *L. draba*. We also collected plants and seeds to start a greenhouse colony of *L. draba*.

Szucs: For biological control of invasive swallow-wort vines over 900 adult *Hypena opulenta* moths were released at two locations in Michigan. Monitoring of prior releases between 2020-

2023 at 15 field sites continued across Michigan. Establishment success has not been confirmed to date. For biological control of spotted wing drosophila over 5000 *G. kimorum* were released across 7 field sites in Michigan. These are 2nd year releases for this agent at the given locations. Establishment success of the parasitoid wasps has not been confirmed yet.

b) Incomplete work or areas needing further investigation:

Adams: Our lab will continue to monitor for released parasitoids targeting spotted wing drosophila. *G. kimorum*, and *Leptopilina japonica* have not been recaptured. *Pachycrepoideus vindemmiae* can be found in large numbers.

Littlefield: Timing of redistributions of the mite *A. drabae*, from cooler sites to warmer sites where plant phenology maybe more advanced and less susceptible to gall induction may be problematic. We will be looking at better methods for mite redistribution within a broader geographic area.

Ramirez: Future work includes establishing a lab colony of *A. drabae* and releasing in pre-identified field sites in New Mexico as mites become available.

Szucs: Establishment success of *G. kimorum* should be monitored at the release sites. So far only releases took place and no monitoring in Michigan.

Objective 1f. Evaluate natural enemy efficacy and study ecological/physiological basis for interactions.

1) Arthropod or weed pests

a) Degree to which objective has been accomplished:

Andreas: Conducted post-release monitoring for four weed systems (diffuse knapweed, Russian knapweed, Dalmatian toadflax, and St. Johnswort). Established and conducted pre-release monitoring for three weed systems (whitetop, flowering rush, and yellow starthistle). Monitoring is conducted yearly.

Collier: We novelly applied a habitat suitability modelling approach commonly used in conservation and wildlife management, “MaxEnt,” to our weed biological control system. We analyzed two types of occurrence data for the Canada thistle gall fly, *Urophora cardui*: existing records of galls observed at release sites by weed managers, and our own observations based on visits to release sites during 2023 and 2024. Analyses using MaxEnt identified several environmental variables that best predict the presence of *U. cardui*. Temperature and precipitation during the spring plus distance to wet habitat were the most predictive of successful establishment of sustained *U. cardui* populations in Wyoming. This research shows that analyses using MaxEnt can yield insight into the factors that limit establishment of weed biological control agents. A presentation about the results of the habitat suitability modeling for *U. cardui* was given at an annual meeting of Wyoming weed managers.

Hoddle: The potential biotic resistance of native egg parastioids in the genus *Anastatus* (Hymenoptera: Eupelmidae) towards spotted lanternfly, *Lycorma delicatula* (Hemiptera: Fulgorida) was assessed in the quarantine facility at UCR. Undescribed native *Anastatus* sp. reared from eggs of species of native western U.S. lantern flies in Arizona were able to parasitize *L. delicatula* eggs. An additional native species, *A.reduvii*, also successfully parasitized *L. delicatula* eggs. These native species of Anastatus may lessen the severity of impacts by *L. delicatula* when this pest eventually invades California.

Littlefield: Our initial releases of *A. drabae* for hoary cress were made six seasons ago. Over this time, we have observed not only increased number of stems infested but an increase in gall intensity. We have begun to characterize mite impact on seed production, plant height and secondary branching. As expected, the number of seeds produced decreased with percent infestation of the crown. Very few seeds were produced at higher gall intensities (86-100% reduction). A slight reduction in height was observed at the higher impact categories. However, the impact of galls may differ as to year or site/habitat.
McDonnell: The malacopathogenic nematode, *Phasmarhabditis hermaphrodita* and/or emulsions of cedarwood essential oil can be used to reduce damage to lettuce grown in propagators by the invasive slug, *Deroceras reticulatum*.

Szucs: Experiments were conducted with the biocontrol agent *A. itadori* that was released to control invasive knotweeds to assess how hybridization among two different strains of *A. itadori* may impact their host choice and developmental success. We found that all that both the parental and hybrid populations of *A. itadori* laid eggs on all three targeted knotweed species (Japanese, Giant and Bohemian) but some of the choices were maladaptive because the eggs failed to develop. Hybrid *A. itadori* had intermediate or higher survival on given knotweed species compared to their parents. These results can inform release tactics of *A. itadori* on different knotweed species in different climatic regions.

b) Incomplete work or areas needing further investigation:

Adams: Our lab has not been able to measure an ecological effect on target pests. It will likely be years before we can measure an impact due to natural enemies.

Collier: My graduate student and I continue to research the environmental factors that limit long-term establishment of a weed biological control agent, an imported fly from Europe that attacks Canada thistle, a problematic weed across the northern U.S.

Hoddle: All aspects of proactive work on assessing biotic resistance of native egg parasitoids towards *L. delicatula* have been completed and this work is at an advanced stage of preparation for submission to a peer reviewed scientific journal.

Littlefield: We will further characterize *A. drabae* impact in the future. SIMP transects have been established adjacent to several of these releases to determine changes in plant density. To help land managers to more easily characterize gall intensity, we are trying to develop a simplified rating system to assess the extent of plant infestation. Non-target utilization of other mustard

species by the mite will continue to be monitored; especially on *L. campestre*, an introduced annual weed.

Szucs: Establishment success of *A. itadori* in Michigan has not been confirmed despite the release of over 40,000 adults between 2022-2023.

Objective 2a. *Characterize and identify pest and natural enemy communities and their interactions.*

1) Arthropod or weed pests

a) Degree to which objective has been accomplished:

Heraty: A graduate student in my lab (Krissy Dominguez) is addressing relationships in the Gonatocerus species group, which include important egg parasitoids of sharpshooters in California. This will be the first molecular analysis of the group and will try to address some recent controversial taxonomic changes that have been made at the genus level.

Jabbour: Worked to identify carabid beetles collected from a study examining how cover crops affect beneficial arthropods. This work was presented at the Entomological Society of America North Central Branch meeting in 2024.

Mauck: We performed experiments in both the laboratory and field to evaluate the effects of biological material derived from industrial insect rearing (insect frass) on soil microbes that prime plant defenses against arthropod pests and directly suppress soil pathogens. We collected samples from soil amended with frass materials over time to correlate microbial communities with frass mineralization. DNA extraction and sequencing to identify microbial communities is ongoing. We obtained additional funding from a Specialty Crop Block Grant to continue some of this work based on initial W5185 funding and are pursuing additional funding from USDA.

Ramirez: Research was conducted on *Hypera postica* (alfala weevil), *Acyrthosiphon pisum* (pea aphid), and *Spodoptera exigua* (beet armyworm). Activities included (1) field site identification and sampling to evaluate natural enemy and pest communities in New Mexico alfalfa, (2) manipulation of natural enemy and life stage diversity in field cages to evaluate impact on pest suppression, (3) a survey of alfalfa field sites with varied insecticide use to evaluate natural enemy and pest communities in New Mexico and (4) gathering selective and broad-spectrum insecticides to conduct bottle assays on pest and natural enemies.

Rankin: We have been sampling pests and natural enemies in CA vineyards and developing PCR-based screens for 6 major pests and 2 groups of common native natural enemies. We have extracted fecal samples from >200 bluebirds and 100 tree swallows that nest in these vineyards.

b) Incomplete work or areas needing further investigation:

Jabbour: Beetles sampled from the cover crop study continue to be identified to species. Once this is complete, the data will be summarized in draft a manuscript for future publication.

Mauck: We need to complete sequencing and bioinformatic analysis for microbiome characterization, as well as community analyses to identify key players that may be isolated for future study.

Ramirez: Several aspects of *H. postica*, *A. pisum*, and *S. exigua* require further investigation, including, (1) evaluation of environmental and landscape factors that impact natural enemy and pest communities, (2) continuing field cage evaluation of natural enemies for additional alfalfa pests, (3) evaluating changes in insecticide use on natural enemy and pest communities, and (4) development of pest and natural enemy sensitivity curves to insecticides used in alfalfa.

Rankin: We are developing species-specific primers for two important parasitoid wasps that prey on major pests in CA vineyards. We are starting to screen the fecal samples of bluebirds and tree swallows for the presence of grape pests and their natural enemies. This will help us assess whether these birds are providing net pest control services in vineyards.

Objective 2b. Identify and assess factors potentially disruptive to biological control.

1) Arthropod or weed pests

a) Degree to which objective has been accomplished:

Hoddle: Invasive Argentine ants are a significant impediment to biological control agents attacking honeydew producing hemipterans. Ants harvest honeydew from sap sucking pests and in return ants protect these pests from their natural enemies. Recently completed work indicated that when ants are controlled with biodegradable hydrogel beads that contain sugar water laced with insecticide and flowering cover crops which provide natural enemies with pollen and nectar, are also available, pest populations decrease significantly because of enhanced natural enemy activity.

Rankin: As detailed above, we have led the diet analysis of avian predators to assess the degree to which these species potentially disrupt pest control via the consumption of natural enemies and/or biocontrol agents.

Szucs: The resistance of invasive spotted wing drosophila was tested against parasitism prior to the release of the parasitoid biocontrol agent *G. kimorum* to better understand factors that may impact the effectiveness of this biocontrol agent. We found large differences in resistance against parasitism among seven populations of spotted wing drosophila across Michigan that ranged between 12-48% regionally. This can result in variable biocontrol success locally. The phenology of invasive lily leaf beetles was assessed in newly invaded areas in Michigan. This served to understand the timing of the different life stages under the climatic conditions in Michigan so that future biocontrol agent releases can be conducted appropriately. Three parasitoid species established for lily leaf beetle biocontrol in New England that have successfully controlled the pest there. An attempt was made in 2024 to import these biocontrol agents to Michigan, but emergence rate was too low for releases.

b) Incomplete work or areas needing further investigation:

Szucs: Follow up study is needed once *G. kimorum* is established to understand how spotted wing drosophila populations evolve in response to attack by biocontrol agents. New parasitoid importation from Switzerland may be warranted because their collection from established populations in New England appears difficult, partly due to their success at suppressing the pest and subsequently persisting at low populations.

Objective 2c. Implement and evaluate habitat modification, horticultural practices, and pest suppression tactics to conserve natural enemy activity.

1) Arthropod or weed pests

a) Degree to which objective has been accomplished:

Hoddle: Planting flowering cover crops in commercial citrus orchards was demonstrated to increase the impacts of natural enemies, especially hover flies (Syrphidae), against sap sucking pests (i.e., hemipterans) infesting citrus trees. The positive effects of cover crops was enhanced further when ants that are antagonistic towards natural enemies are controlled via the deployment of biodegradable hydrogel beads infused with 25% sucrose solution and very low amounts of insecticide.

b) Incomplete work or areas needing further investigation:

Hoddle: Results from field studies evaluating the benefits of planting flowering crops in commercial citrus orchards are being analyzed and prepared for publication sometime in 2025.

Objective 3a. Assess biological characteristics of natural enemies.

1) Arthropod or weed pests

a) Degree to which objective has been accomplished:

Mauck: We performed experiments to evaluate the potential for materials derived from insect rearing operations (frass, insect bodies and exoskeletons) to protect plants against insect vectors and vector-borne plant viruses. We conducted a field experiment evaluating efficacy against an aphid-transmitted pathogen and laboratory/greenhouse experiments evaluating efficacy against a thrips-transmitted pathogen, and thrips themselves. We found evidence of efficacy against the thrips-transmitted pathogen and are pursuing additional funding from the USDA to expand this work.

b) Incomplete work or areas needing further investigation:

Mauck: Follow-up work will focus on mechanisms of virus resistance, including looking at effects on virus titers, dosage effects, and expression of defense genes.

Objective 3b. Develop procedures for rearing, storing, quality control and release of natural enemies, and conduct experimental releases to assess feasibility.

1) Arthropod or weed pests

a) Degree to which objective has been accomplished:

Andreas: Our research group is refining knotweed psyllid, *A. itadori*, rearing for field releases. Began rearing the knotweed psyllid Murakami strain, in addition to the Hokkaido and Kyushu strains. Released 47,500 psyllids at hybrid and giant knotweed sites across western Washington. We assessed multiple release techniques and will survey for psyllid overwintering in 2025.

Dillman: We have been optimizing freezing procedures for a new species of entomopathogenic nematode from Thailand, this would be useful for long-term storage. We are also working to develop genetic manipulation techniques in currently available EPNs.

Leppla: *Trichopoda pennipes*, a tachinid fly, parasitizes *A. tristis* and other coreids in the Southeast, along with the southern green stinkbug, *Nezara viridula*, and additional species of pentatomids. It also frequently oviposits on the eastern leaffooted bug, *Leptoglossus phyllopus*, another coreid. Therefore, three host-determined strains of *T. pennipes* seemed to occur from coreids in the Northeast, pentatomids in the South, and bordered plant bug in California. To determine if *T. pennipes* from these host species are host-determined strains, mated females were given a choice between *A. tristis*, *N. viridula*, and *L. phyllopus* adults for oviposition. The females oviposited primarily on their parental host species for 1-2 generations. Mitochondrial DNA analysis revealed separate markers for two parasitoid lineages, one from both *N. viridula* and *L. phyllopus* and another from only *L. phyllopus*.

Littlefield: A colony of the oxeye daisy root moth, *Dichrorampha aeratana*, has been initiated at the containment facility at Montana State University. CABI, Switzerland collected and shipped a total of 1,200 eggs to Montana State in 2023 and 2024. In 2023 larvae were transferred to plants, then overwintered in cold storage. Thirty-three adults (50:50 male: female) emerged from mid-May to June. Approximately 495 larvae were transferred to oxeye daisy plants. These were supplemented in 2024 with additional eggs from CABI. Infested plants were removed from our greenhouse and are being acclimated for overwintering. *Dichrorampha aeratana* was recommended for release by Technical Advisory Group on the Biological Control of Weeds in 2022. In 2024, a biological assessment was reviewed by the US Fish & Wildlife Service for any threatened or endangered species concerns and release documentation has been submitted for Tribal consultation.

Mauck: We continued work to understand the biological characteristics of frass and how they change over time. We have monitored frass elemental composition and have isolated chitin with a pilot procedure. We obtained additional funding from a Specialty Crop Block Grant to continue this work based on initial W5185 funding.

b) Incomplete work or areas needing further investigation:

Leppla: *Trichopoda pennipes* has considerable potential as an augmentative biological control agent, parasitizing insects from at least six true bug families: Coreidae, Largidae, Pentatomidae, Scutelleridae, Pyrrhocoridae, and Alydidae, with species from 15 genera. However, *T. pennipes* causes high levels of parasitism in some hosts, locations and cropping systems but not others. Therefore, research is being conducted to determine how to produce *T. pennipes* for augmentative biological control of specific pest stink bugs. The research objectives are: 1) design and test efficient and reliable systems for rearing host pentatomids and coreids for producing host-specific *T. pennipes* lines and 2) determine the preference of *T. pennipes* for alternative pentatomid and coreid hosts and associated host suitability. Studies are needed on a range of these parasitoid-host relationships, including how genetic and phenotypic variation of the host affects parasitoid host selection and suitability.

Littlefield: A *D. aeratana* colony will continue to be maintained and supplemented at Montana State University. Rearing methods will continue to be improved. Initial releases will be made in Gallatin County, MT. Effective release methods (larval transfers verse release of adults) will be compared. Subsequent releases are planned at multiple locations in western Montana with varying elevations, latitudes, and habitats to determine the optimum conditions for establishment and efficacy of *D. aeratana*.

Objective 3c. Implement augmentation programs and evaluate efficacy of natural enemies.

1) Arthropod or weed pests

a) Degree to which objective has been accomplished:

Dillman: We have sequenced the genome of *Steinernema hermaphroditum*, an entomopathogenic nematode that could be useful in biological control. We hope to publish the results of that analysis soon.

Skinner: A field trial of biopesticides for Fusarium was initiated, testing RootShield Plus WP; RootShield Plus G; Zerotol 2.0; and Terragrow, using various treatment methods: dip, soil drench, and controls with tap water and untreated controls. Treatments were evaluated based on saffron flower abundance and yield measured throughout the blooming season; number of plants with characteristic symptoms of fungal infection; number and size of secondary corms and occurrence of disease and bulb mites; and leaf length. Small differences in saffron yield were detected among treatments in yrs 1 and 2, though differences were not significant. There also was no evidence of Fusarium infection in any treatments. Therefore, there is not sufficient evidence to recommend use of these products to enhance saffron production or prevent disease. Data from these plots will be collected for the next 4 years to determine treatment persistence. The trial was repeated in 2023 and 2024.

b) Incomplete work or areas needing further investigation:

Skinner: In cooperation with USDA-ARS, molecular analysis is underway to determine if any of the myco-based products are colonizing the corm roots. Saffron is a comparatively new crop for the US, and many questions remain on how to grow it. Our semi-permanent plots will provide excellent long-term data on annual yield variation due to weather fluctuations and other variables.

Objective 4: Evaluate Environmental and Economic Impacts and Raise Public Awareness of Biological Control.

Objective 4a. Evaluate the environmental and economic impacts of biological control agents.

1) Arthropod or weed pests

a) Degree to which objective has been accomplished:

Adams: Our lab has shared biocontrol efforts and results at stakeholder meetings (4 per year) and in weekly newsletters shared with a grower listserv, and in extension publications.

Crowder: Our study connected researchers from 20 states on biological control of brown marmorated stink bug. Our work can guide future releases of *T. japonicus* and can be used to prioritize conservation of *Nosema*.

Jabbour: We worked to describe the introduction history of *Bathyplectes curculionis*, to better understand the present status of this biocontrol agent of alfalfa weevil. This work was presented at the Entomological Society of America North Central branch meeting in 2024.

Lara: During 2024, the establishment of *T. japonicus* and its impact on target *H. halys* populations were tracked at urban and agricultural field sites across various California counties with support from the University of California. This project is still underway.

Rankin: As part of our quantification of pest predation, we also aim to assess the ecological and economic impacts of the predators. This involves quantifying response of prey populations (both target pest taxa and non-pest, native taxa) to predatory pressure in the field. In addition to quantifying correlations between pest and predator populations, we aim to evaluating predators' contributions to ecosystem services and using genomic methods to identify cryptic trophic links in invaded food webs. These efforts aim to further our understanding of trophic dynamics in natural and agroecosystems in California and the Pacific. These efforts are ongoing.

b) Incomplete work or areas needing further investigation:

Jabbour: We are preparing a publication for the public that describes the introduction history of *B. curculionis*.

Objective 4b. Develop and implement outreach activities for biological control programs.

1) Arthropod or weed pests

a) Degree to which objective has been accomplished:

Adams: Our lab has held annual field days to discuss biocontrol efforts with stakeholders. These efforts are ongoing.

Andreas: Ten weed biocontrol related presentations were provided at conferences, workshops, and university guest lectures. Pesticide re-certification credits were provided at four events.

Hoddle: During this reporting period three meeting were organized. Two meetings (were jointly organized with CAPCA (California Association of Pest Control Advisers) branches in Ventura and San Diego Counties. Meeting content covered the biology and management of invasive pests of importance to agriculture, and urban and natural areas. Aspects of biological control programs were discussed where relevant (Ventura, CA, 97 meeting attendees, 20 June 2024; Temecula, CA, 58 meeting attendees, 28 August 2024). A third meeting focused on the biology and management of South American palm weevil, *Rhynchophorus palmarum*.UCR-UCCE 2024 South American Palm Weevil Workshop (Bonita, CA, 65 attendees, 22 October 2024). 29 extension presentations were given on biological control of pests during 2024.

Heraty: As part of our NSF project, we developed online modules that explain parasitoids to high school students, Master Gardeners and other venues (http://outreach.chalcid.org/). The approach is to teach more upper-division students or adults about the importance of parasitoids in biological control. We developed outreach materials to teach about chalcidoids and other parasitic Hymenoptera in the classroom. The idea is to develop independent modules for classrooms centered on yellow pan trap 'observatories' to discuss 'true' biodiversity. Our ideas for outreach were vetted through a broad group of local teachers, and extension researchers at UC Riverside and Texas A&M University. We developed an online PowerPoint presentation, with audio, on biodiversity of parasitic Hymenoptera that we have been able to get introduced into high school curriculums on ecology.

Lara: In July 2024, a biological control and IPM workshop was co-organized with the University of California in Monterey County. The workshop provided pest research updates to students training to become future farmers.

LeBeck: Maintained an association website to aid in networking for the commercial biocontrol industry. Maintained a database of all commercially produced natural enemies for sale in North America for biocontrol in IPM systems. Co-organized a symposium session about the status of commercial biological control worldwide for the IOBC International IPM Conference held in Costa Rica (summer 2024).

Skinner: We have an active outreach program to share information about saffron cultivation in general, reaching over 1,000 growers annually. This includes reporting results from this research as they become available. While our primary objectives deal with IPM in saffron production, we realize new saffron growers need help with many aspects of establishing saffron as a crop within

a diversified farm operation. Therefore, our outreach activities are critical for supporting these pioneer growers. It also answers questions about infection by Fusarium or bulb mites, which are problems in onion, garlic and various ornamental bulb plants (lilies, tulips, etc.). We also continue to host IPM workshops with presentations on biocontrol and work with growers in high tunnels and greenhouses, with a strong focus on enhancing biocontrol efficacy in commercial settings.

b) Incomplete work or areas needing further investigation:

Hoddle: Development and delivery of outreach activities will require constant work as new invasive pest problems need addressing.

Skinner: A saffron workshop will be held in March 2025 to continue to discuss the potential of soil treatments to enhance saffron production. A workshop is scheduled for January 2025 on greenhouse IPM, which will include presentations on biological control of aphids. An online webinar will be held for New Americans in March 2025. A hands-on session on biological control in ornamentals will be held in Oct. 2025.

4. USEFULNESS OF FINDINGS (According to the guidelines, impacts are the economic, social, health or environmental benefits derived by the intended users. Further, each impact statement should be a single sentence and should quantitatively define the benefit.)

a) Outputs/Impacts:

Collier: Weed managers now have specific guidance for *U. cardui*. Having a tool to guide decisions about release strategies, which may better promote success, is important for increasing the benefits to the public. Weed managers in Wyoming are also now aware of the existence of a new tool for making predictions that relies on data that they can collect, giving additional incentive to collect occurrence data at release sites.

Dillman: The discovery and description of new species of entomopathogenic nematodes may lead to their effective use in biological control. Every new EPN species may help alleviate insect herbivory of important agricultural crops.

Hoddle: Impacts of work completed here have been significant and have had far reaching positive impacts. For example, demonstration that biodegradable hydrogel beads can be used to successfully control invasive Argentine ants, has resulted in CA DPR reducing restrictions on applications of beads to soil in citrus orchards. Extension meetings and presentations on biological control of invasive pests of importance to California have reached at least 739 people (estimate based on meeting attendance records). Meeting evaluations, either using SLIDO or paper questionnaires indicated that new knowledge gain increased and that the information presented at the meetings and via talks was useful and would be used for management of invasive pests (i.e., ant control, conserving natural enemies, and reductions in insecticide use).

Heraty: Chalcidoidea are economically and biologically one of the most important groups of insects, and yet very little is known of their taxonomy (identification) or relationships. Our research is identifying new potential biological control agents for use against pestiferous leafminers on citrus, whitefly on citrus, aphids on wheat and other crops, and for wasps attacking pestiferous ants. New research on cryptic species complexes (morphologically identical but reproductively and biologically distinct species) using molecular markers has tremendous potential for the identification of new biological control agents. Identification keys and other products will help other researchers to better understand the impact of these groups and identify gaps that aid in targeting new biological control agents.

Jabbour: Our work helps to integrate past and current management efforts with biological control programs.

Lara: Classical biological control agents targeting invasive arthropod pests are being reared and redistributed by CDFA's biological control program to reduce pest densities for the benefit of specialty crop growers, land managers, and urban communities. The knowledge generated from various target pest projects (e.g., *A. planipennis*, *H. halys*, *Plutella xylostella*, *P. absoluta*) has been disseminated to more than 100 stakeholders through extension events and publications during 2024.

LeBeck: The Association of Natural Biocontrol Producers connects commercial rearing and distribution professionals, university, and USDA biocontrol scientists, and the USDA regulatory staff to maintain the availability and quality of natural enemies used in agriculture today.

Littlefield: Currently only one agent, a gall mite (*A. drabae)*, has been approved for release in the US for the control of three hoary cress (Lepidium) species. In early summer 2019 two releases were made in Montana, and as of 2024, releases have been made at 26 sites in Montana. The mite has successfully overwintered and has established in Montana. Galls have been observed at approximately 70% of our releases, and its status of 19% of the releases is unknown (i.e. new releases). Gall material has also been provided to the Nez Perce Biocontrol Center in Idaho, the Colorado Department of Agriculture Insectary in Palisades, Wyoming Weed & Pest and University of Wyoming.

Mauck: Studying frass effects on microbial communities will determine if this agricultural product can enhance organisms that control soil pathogens and boost plant immunity to pests. Studying frass and insect component effects on plant immunity to vectors and pathogens they transmit will determine if these rearing by-products can be used as part of integrated pest/disease management programs. Support from the W5185 program has enabled extramural grant applications that yielded $467,000 in additional support for discussed projects in this fiscal year.

Park: Sensory Ecology of *M. borraginis* contributed to the pre-release risk assessment for federally listed threatened and endangered plant species in Boraginaceae (Park et al., 2024). The UV-marking application of leaf beetles will be applied to *C. basicorne* to allow female weevils to explore a rosette stage of yellow starthistle for the mass-rearing technique (Park, 2024). The description of the new natural enemy for invasive box tree moths will be beneficial for implementing a proactive biological control program in the United States (Kim et al., 2024).

Rankin: Quantification of ecosystem services/disservices and identification of management strategies and landscape features associated with these services/disservices help resource managers and environmental stakeholders develop prioritization frameworks.

Szucs: *Ganaspis kimorum* releases should result in reduction on pesticides used in soft fruit crops as they reduce populations of spotted wing drosophila on the landscape level. *Aphalara itadori* hybridization study provides alternative recommendations for releasing the biocontrol agent to maximize its chances of establishment.

Skinner: Over 100 growers gained knowledge about saffron cultivation and specifically biological control options, of which 50% indicated they learned new information they will use in the future. Over 200 growers gained knowledge about biocontrol through our greenhouse and high tunnel IPM educational programs, of which over 75% indicated they learned new techniques they will adopt. Over 1,000 saffron growers subscribe to the UVM email list `Saffronnet" where at least 1,200 emails have been sent out distributing information about saffron cultivation around the country. Ten different factsheets produced by UVM on saffron cultivation and post-harvest handling were sent out to 500 different people over the past year, to enhance saffron production practices. The UVM Saffron website received over 4,000 hits where information on saffron cultivation is provided. The UVM Greenhouse and High Tunnel websites received over 2,000 hits where information on IPM and biological control is provided.

b) Projected outputs or impacts:

Littlefield: In Montana, *A. drabae* populations have significantly increased in both number of stems infested and galling intensity of plants. Mites have started to disperse from these release sites. Impacts will continue to be monitored. We will initiate redistributed mites from well-established field sites and we will continue to develop better release techniques to make this agent available over a greater geographic area. We hope to release the first biocontrol agent (the root moth, *D. aeratana*) on oxeye daisy in 2025 (pending release permit).

Park: Improving mass-rearing protocol of *C. basicorne* by topically applying insect hormones and changing gut microbial diversity.

Skinner: Saffronnet, UVM's saffron listserv, will continue to meet grower needs with regard to sound cultivation methods. The UVM Entomology Research Lab will continue to maintain email lists and websites to disseminate information on biological control. We continue to have an active outreach program to share information about saffron cultivation and IPM specifically, reaching 1,000's of growers annually. This outreach includes reporting results from this research as they become available, and general information on biological control in protected environments.

5. PUBLICATIONS ISSUED AND MANUSCRIPTS APPROVED
(Any common format is acceptable here. Publication date should be within the last year)

1. Andreas, J.E., et al., 2024. Poison Hemlock (*Conium maculatum*): Biology and Management in the Western USA. NAISMA, Milwaukee, WI. NAISMA-IPM-2024-2-POISON HEMLOCK.

2. Andreas, J.E., et al., 2024. Field Bindweed (*Convolvulus arvensis*): History and Ecology in North America. In: R.L. Winston, Ed. Biological Control of Weeds in North America. NAISMA, Milwaukee, WI. NAISMABCW-2024-10-FIELD BINDWEED-P. https://bugwoodcloud.org/resource/files/31489.pdf

3. Andreas, J.E., et al., 2024. Field Bindweed Biocontrol Agents: History and Ecology in North America. In: R.L. Winston, Ed. Biological Control of Weeds in North America. NAISMA, Milwaukee, WI. NAISMA-BCW-2024-10-FIELD BINDWEED-A. https://bugwoodcloud.org/resource/files/31490.pdf

4. Baniya A., et al., 2024. *Steinernema adamsi* n. sp. (Rhabditida: Steinernematidae), a new entomopathogenic nematode from Thailand. Journal of Parasitology 110(1): 22-39. https://doi.org/10.1645/23-60

5. Bitume, E.V., et al., 2024. Establishment of the wasp *Tetramesa romana* for biological control of *Arundo donax* in northern California and the role of release plot manipulation. Biol. Control 192:105489. https://doi.org/10.1016/j.biocontrol.2024.105489

6. Cong, L., et al., 2024. Determination of the relationship between the numbers of Argentine ant, Linepithema humile, on irrigation pipes and tree trunks to facilitate automated monitoring in Southern CA citrus orchards. J. Econ. Entomol: https://doi.org/10.1093/jee/toae279

7. Conlong, D.E., et al., 2024. Chapter 7: Insect Mass Rearing for IPM Applications, in: Karsten, M., Terblanche, J. S. (Eds.), Principles of Integrated Pest Management: A Southern African Perspective. CABI, Wallingford, UK.

8. Cruaud, A., et al., 2024. The Chalcidoidea bush of life – a massive radiation blurred by mutational saturation. Cladistics 40:34-63. https://doi.org/10.1111/cla.12561

9. Denver, D.R., et al., 2024. *Phasmarhabditis hermaphrodita*, a biocontrol nematode species, infects and increases mortality of *Monadenia fidelis*, a non-target terrestrial gastropod species endemic to the Pacific Northwest of North America. PLoS One 19:e0298165. https://doi.org/10.1371/journal.pone.0298165

10. Frey, M.A., et al., 2024. Introduction and spread of the wrinkled snail, *Xeroplexa intersecta* (Poiret, 1801) (Geomitridae) in the Pacific Northwest of North America. Am. Malacol. Bull. https://doi.org/10.4003/006.041.0101

11. Gómez-Marco, F., et al., 2024. Proactive biological control of spotted lanternfly: parasitism and host feeding behavior of *Anastatus orientalis* (Hymenoptera: Eupelmidae) on *Lycorma delicatula* (Hemiptera: Fulgoridae) egg masses. Biol. Control 195:105551.5. https://doi.org/10.1016/j.biocontrol.2024.105551

12. Herreid, J.S. and Jabbour, R. Accepted. "Chalcidoidea as Hyperparasitoids" In: Heraty, J.M. and Woolley, J.B. (eds) Chalcidoidea of the World, CABI, Wallingford, UK. Herreid, J.S., Rand, T.A., Cockrell, D.M., Peairs, F., and Jabbour, R, 2024. On-farm harvest timing effects on alfalfa weevil across the Intermountain West region of the US. Frontiers in Insect Science 4:1324044. https://doi.org/10.3389/finsc.2024.1324044

13. Hogg, B., et al., 2024. Developing proactive control options for an invasive tomato pest. CAPCA 27:40-44.

14. Kim, S., et al., 2024. A new species of Braunsia (Hymenoptera, Braconidae, Agathidinae), a natural enemy of *Cydalima perspectalis* (Lepidoptera, Crambidae) from South Korea: species desciption and notes on its biology. J. Hymenopt. Res. 97:915-936. https://doi.org/10.3897/jhr.97.135728

15. Kresslein, R., et al., (in press). Nomenclatural spring cleaning: tidying Aphelinidae of taxa that do not spark joy, and a new species of *Prococcobius Hayat* (Aphelinidae: Coccophaginae). J. Nat. Hist.

16. Leppla, N.C., et al., 2024. Status and Trends of Biological Control Research, Extension, and Education in the United States. Ann. Ent. Soc. Amer. 117:1-9. https://doi.org/10.1093/aesa/saae005

17. Mc Donnell, R.J., et al., 2024. Slugs: A Guide to the Invasive and Native Fauna of California. 2nd Edition. UCANR Publications. https://anrcatalog.ucanr.edu/pdf/8336.pdf

18. McDonald-Howard, K-L., et al., 2024. An investigation into the combination of the parasitic nematode *Phasmarhabditis hermaphrodita* and cedarwood oil to control pestiferous slugs. Crop Prot 179:106601. https://doi.org/10.1016/j.cropro.2024.106601

19. Milosavljevic, I., et al., 2024. Spinosad-infused biodegradable hydrogel beads as a potential organic approach for Argentine ant, *Linepithema humile* (Mayr) (Hymenoptera: Formicidae) management in CA citrus orchards. J. of Appl. Entomol. 148:117-127. https://doi.org/10.1111/jen.13203

20. Park, I., 2024. Refining *Gastrophysa atrocyanea* (Coleoptera: Chrysomelidae) identification using UV marking in whole-plant assessment. J. Asia. Pac. Entomol. 27:e102251. https://doi.org/10.1016/j.aspen.2024.102251

21. Park, I., et al., 2024. Non-destructive environmental safety assessment of threatened and endangered plants in weed biological control. PeerJ 12:e16813. https://doi.org/10.7717/peerJ.16813

22. Randall, C.B., et al., 2024. Poison Hemlock (*Conium maculatum*): History and Ecology in North America. In: R.L. Winston, Ed. Biological Control of Weeds in North America. North American Invasive Species Management Association, Milwaukee, WI. NAISMA-BCW-2024-22-POISON HEMLOCK-P. https://bugwoodcloud.org/resource/files/31428.pdf

23. Randall, C.B., et al., 2024. Poison Hemlock Biocontrol Agents: History and Ecology in North America. In: R.L. Winston, Ed. Biological Control of Weeds in North America. North American Invasive Species Management Association, Milwaukee, WI. NAISMA-BCW-2024-22-POISON HEMLOCK-A. https://bugwoodcloud.org/resource/files/31429.pdf

24. Yanega, D., et al., 2024. Description of a new genus of North and Central American planthoppers (Hemiptera: Fulgoridae) with fourteen new species. Zootaxa 5443(1). https://doi.org/10.11646/zootaxa.5443.1.1

25. Irvin, N., et al., 2024. Monitoring of coccinellid (Coleoptera) presence and syrphid (Diptera) species diversity and abundance in southern California citrus orchards: implications for conservation biological control of Asian citrus psyllid and other citrus pests. Florida Entomologist; 107(1). https://doi.org/10.1515/flaent-2024-0060

26. Yoshimoto, A., M. Szucs, 2024. Could hybridization increase establishment success of the biological control agent *Aphalara itadori* (Hemiptera: Aphalaridae) against invasive knotweeds? Ecology and Evolution. 14. E10936. https://onlinelibrary.wiley.com/doi/10.1002/ece3.10936

27. Zhu, G., et al., 2024. Assessing geographic dimensions of biological control for *Halyomorpha halys* in United States. Entomologia Generalis 44: 895-904. https://doi.org/10.1127/entomologia/2024/2528

See next page for Appendix C: Arthropod Pests. Review the species lists to ensure all relevant species are included. Additions and changes in species names are welcome. Indicate new text by highlighting.

Appendix C

W5185 Current Target Pest Groups and Species (2022)

Arthropod Pests

Aphids: (1) *Acyrthosiphon pisum*, (2) *Aphis craccivora,* (3) *Aphis gossypii*, (4) *Melanocallis caryaefoliae*, (5) *Monellia caryella*, (6) *Monelliopsis pecanis*, (7) *Myzocallis walshii,* (8) *Myzus persicae,* (9) *Pentalonia nigronervosa*, (10) *Toxoptera citricida*, (11) *Diuraphis noxia,* (12) Unspecified species

Beetles: (1) *Ceutorhynchus obstrictus,* (2) *Diabrotica virgifera virgifera*, (3) *Hypera postica,* (4) *Lilioceris lilii,* (5) *Oulema melanopus,* (6) *Cylas formicarius,* (7) *Oryctes rhinoceros*, (8) *Rhynchophorus ferrugineus,* (9) *Rhynchophorus vulneratus,* (10) *Rhynchophorus palmarum*, (11) *Agrilus auroguttatus,* (12) *Hypothenemus hampei*, (13) *Leptinotarsa decemlineata*, (14) *Anoplophora glabripennis*,(15) *Anaplophora chiniensis,* (16) *Pyrrhalta viburni,* (17) *Euwallacea fornicatus* species complex, (18) *Agrilus planipennis* (19) Unspecified species

Heteroptera: (1) *Anasa tristis*, (2) *Erythroneura variabilis,* (3) *Leptoglossus clypealis*, (4) *Lygus* spp., (5) *Nezara viridula*, (6) *Bagrada hilaris*, (7) *Halyomorpha halys*, (8) *Pseudacysta perseae*, (9) *Megacopta cribraria*, (10) *Leptoglossus zonatus,* (11) *Erythroneura ziczac,* (12) Unspecified species

Lepidoptera: (1) *Acropsis muxnoriella*, (2) *Acrolepiopsis assectella*, (3) *Adoxophyes orana,* (4) *Amyelois transitella*, (5) *Anarsia lineatella*, (6) *Choristoneura rosaceana*, (7) *Enarmonia formosana,* (8) *Heliothis zea*, (9) *Marmara* spp., (10) *Pandemis limitata*, (11) *Pandemis heparana*, (12) *Pectinophora gossypiella*, (13) *Phyllocnistis citrella*, (14) *Plutella xylostella*, (15) *Spodoptera exigua* (16) *Epiphyas postvittana,* (17) *Lobesia botrana,* (18) *Stenoma catenifer,* (19) *Cydalima perspectalis*, (20) *Phthorimaea absoluta*, (21) Unspecified species

Sessile Hemiptera (Sternorrynchus):

(1) *Aonidiella aurantii*, (2) *Coccus pseudomagnoliarum,* (3) *Dysmicoccus* brevipes, (4) *Dysmicoccus neobrevipes*, (5) *Glycaspis brimblecombei*, (6) *Maconellicoccus hirsustus*, (7) *Planococus ficus*, (8) *Pseudococcus maritimus*, (9) *Pseudococcus viburni*, (10) *Quadraspidiosus perniciosus*, (11) *Saissetia oleae*, (12) *Icerya seychellarum*, (13) *Icerya purchasi*, (14) *Aspidiotus destructor*, (15) *Pseudaulacaspis pentagona*, (16) *Quadraspidiotus juglansregiae,* (17) *Quadrastichus erythrinae,* (18) *Diaphorina citri*, (19) *Euphyllura olivine*, (20) *Bactericera cockerelli*, (21) *Rhipicephalus annulatus,* (22) Unspecified species

Fruit flies (tephritids*)*:
(1) *Zeugodacus cucurbitae*, (2) *Bactrocera dorsalis,* (3) *Bactrocera latifrons*, (4) *Bactrocera oleae*, (5) *Ceratitis capitata,* (6) Unspecified species

Whiteflies: (1) *Bemisia* spp., (2) *Aleurodicus dugesii*, (3) *Paraleyrodes* spp., (4) Unspecified species.

Hymenoptera: (1) *Wasmannia auropunctata*

Other arthropods:
(1) *Cacopsylla pyricola*, (2) *Cephus cinctus,* (3) *Delia radicum,* (4) *Eucalyptolyma maideni*, (5) *Homalodisca vitripennis (= coagulata*), (6) *Liriomyza trifolii*, (7) *Scirtothrips perseae,* (8) *Scirtothrips citri,* (9) *Panonychus citri*, (10) *Tetranychus urticae*, (11) *Tetranychus marianae,*(12) *Tetranychus pacificus* , (13) *Oligonychus perseae,* (14) *Quadrastichus erythrinae,* (15) *Piezodorus guildinii*, (16) *Drosophila suzukii,* (17) *Frankliniella occidentalis*, (18) *Caliothrips fasciatus*,(19) *Contarinia nasturtii*, (20) *Rhipicephalus microplus* (21) Rhipicephalus annulatus (22) *Phytomyza gymnostoma* (23) *Lycorma delicatula* (24) *Neoscapteriscus spp.,* (25) *Hamaephysalis spp.,* (27) *Unspecified species*

Weeds

Brassicas: (1) *Alliaria petiolata,* (2) *Isatis tinctoria,* (3) *Lepidium* (= *Cardaria*) *draba,* (4) *Lepidium latifolium, (5) Brassica tournefortii*

Gorse and broom: (1) *Ulex europaeus*, (2) *Cytisus* spp., (3) *Genista monspessulana*, (4) *Spartium junceum*

Grasses: (1) *Arundo donax*, (2) *Phragmites australis*, (3) *Megathrysus infestus,* (4) *Taeniatherum caput-medusae*, (5) *Ventenata* sp., (6) *Bromus tectorum*, (7) *Megathyrsus maximus* (8) *Imperata cylindrica*

Knapweeds: (1) *Rhaponticum* (*Acroptilon) repens*, (2) *Centaurea diffusa*, (3) *Centaurea stoebe subsp. micranthos*, (4) *Centaurea solstitialis*, (5) *Centaurea virgata spp. squarrosa*

Knotweeds: (1) *Reynoutria japonica* (2) *Reynoutria sachalinensis*, (3) *Reynoutria x bohemica*

Purple loosestrife: (1) *Lythrum salicaria*

Saltcedars: (1) *Tamarix ramosissima*, (2) *Tamarix* spp.

Spurges: (1) *Euphorbia esula*, (2) *Euphorbia virgata*

Thistles: (1) *Carduus nutans*, (2) *Carduus tenuiflorus,* (3) *Cirsium arvense*, (4) *Cirsium vulgare,* (5) *Carduus pycnocephalus,* (6) *Onopordum spp.*

Tumbleweeds: (1) *Salsola australis*, (2) *Salsola paulsenii*, (3) *Salsola tragus*

Other weeds: (1) *Chondrilla juncea*, (2) *Convolvulus arvensis*, (3) *Cynoglossum officinale*, (4) *Delairea odorata*, (5) *Dipsacus laciniatus*, (6) *Galium aparine*, (7) *Pilosella* (*Hieracium)* spp., (8) *Hypericum perforatum*, (9) *Linaria dalmatica,* subsp. *dalmatica*, (10) *Linaria vulgaris*, (11) *Peganum harmala*, (12) *Potentilla recta*, (13) *Salvia aethiopis*, (14) *Salvinia molesta*, (15) *Jacobaea vulgaris* (*Senecio jacobaea)*, (16) *Tanacetum vulgare,* (17) *Elaeagnus angustifolia*, (18) *Tribulus terrestris,* (19) *Eichhornia crassipes,* (20) *Pueraria montana*, (21) *Leucanthemum vulgare*, (22) *Mikania micrantha*, (23) *Vincetoxicum* spp., (24) *Ludwigia* spp., (25) *Dittrichia graveolens,* (26) *Mesembryanthemum crystallinum*, (27) *Crupina vulgaris,* (28) *Butomus umbellatus*, (29) Unspecified species.