INVASIVE SPECIES AND POLLINATOR HEALTH RESEARCH UNIT

2023 annual report

USDA-ARS

800 Buchanan Street
Albany, California 94710

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Cover photo: The native spiny phlox, *Plox hoodii*

The Mission

The mission of the Invasive Species and Pollinator Health Research Unit is to develop and transfer integrated, biologically based approaches for the management of pests and the improvement of pollination services.

The Team

The Agricultural Research Service (ARS) is the USDA's chief scientific in-house research arm. The Invasive Species and Pollinator Health (ISPH) research unit is an ARS laboratory equipped with specialized scientific facilities distributed between both Albany and Davis, California. The ISPH is comprised of nine scientists and approximately 30 total employees. The unit's research portfolio spans broad disciplines including invasive plant ecology, weed biological control, insect biological control, and honey bee research. This annual report is comprised of one-page research highlights and accomplishments from 2023, with links to scientific publications for those looking for more information. Email addresses of lead scientists are also provided, feel free to reach out and start a conversation.

The Newest Member

Dr. Jens Beets is the newest member to join the ISPH's team of scientists:

Hello everyone, I recently completed my PhD at North Carolina State University in Fisheries, Wildlife, and Conservation Biology under the direction of Dr. Rob Richardson. My dissertation research focused on the phenology, growth and herbicide management strategies for *Hydrilla verticillata* in flowing water (lotic) systems. This research was prompted by an increasing awareness of aquatic invasive plant species inhabiting lotic systems and anecdotal reports of differences in growth and phenology compared to the populations observed in lake and pond (lentic) systems. This research project involved: (1) monitoring growth and phenology of hydrilla in lotic systems; (2) a mesocosm study identifying growth and phenology of a genetically distinct strain of hydrilla spreading in Connecticut compared to the other biotypes of hydrilla currently in the US; (3) a mesocosm evaluation of intermittent applications of herbicides on monoecious hydrilla; and (4) a mesocosm evaluation of the growth and herbicide management of two invasive *Vallisneria* taxa (including *Vallisneria australis* a recent invader in the Sacramento and San Joaquin River Delta) as compared to other US native *Vallisneria* species. I intend to continue investigating the biology of new invasive species in my new position, with particular interest in aquatic weed growth and phenology, competitive interactions, sensitivity to herbicides and developing integrated plant management strategies.
Feel free to contact me at Jens.Beets@USDA.gov

Invasiveness of yellow flag iris (*Iris pseudacorus* L.) with climate change

Yellow flag iris, native to Europe and west Asia, has invaded wetlands in the Americas, South Africa, east Asia, and Australasia. The magnitude of invasions has increased globally in recent years, including rapid range expansion of populations in Pacific West states. Weed risk assessments have largely relied on limited studies from freshwater habitats, overlooking the capacity for the species to persist in new environments where climate change and sea level rise may alter weed traits, increasing invasion risk and spread. With Dr. Jesus Castillo (Universidad de Sevilla), we analyzed plant community data in populations with and without yellow flag iris along estuarine gradients in the invaded San Francisco Bay-Delta Estuary and native populations in Guadalquivir Estuary (Spain). The iris was associated with high plant species diversity in its native range, but *I. pseudacorus* in California had profound ecological impacts greatly reducing plant species richness and diversity at local and watershed scales independent of soil salinity.

Dispersal and recruitment of yellow flag iris is predominantly by buoyant seeds. Climate change is altering cues that drive germination. We tested germination under light and temperature levels and developed a thermal time model to derive germination thresholds. We also experimentally evaluated germination under fresh to seawater salinity levels and under moist and flooded conditions. Brackish salinity reduced but did not preclude germination. After 55 days floating in seawater, seeds retained high viability and germinated with freshwater exposure suggesting colonization ability following long-distance dispersal with tidal currents. We found that iris has a broad germination niche supporting establishment in a wide range of environments, including at high temperatures and with increased salinity, both predicted to be more frequent with climate change in invaded estuaries.

In 2023, we completed a 5-yr intercontinental field study in invaded California and native Andalusia ranges to determine if functional trait responses of the alien iris to environmental conditions explains its success compared to populations in its native range. We evaluated variation in 15 physiological, morphological and biochemical plant traits and their relationship to 11 environmental variables within 10 study populations along estuarine gradients. We found the invasive iris had greater physiological capacity to adjust to environmental stresses induced by deeper inundation and increased salinity with rising sea level than those in the native range. Knowledge of these trait responses can be applied to improve risk assessments and integrated weed management in invaded estuaries.

Contact: Brenda Grewell (Brenda.Grewell@USDA.gov)

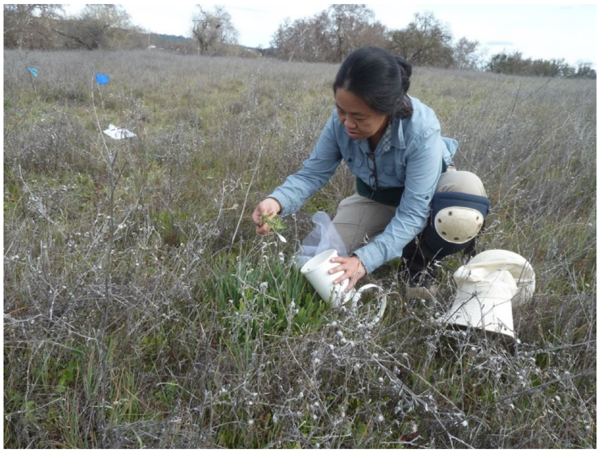
Additional reading:

Grewell et al. 2023. Diversity and Distributions. https://doi.org/10.1111/ddi.13694
Gillard et al. 2022. American Journal of Botany. https://doi.org/10.1002/ajb2.16026
Gallego-Tévar, et al. 2022. Diversity. https://doi.org/10.3390/d14050326
Grewell et al. 2021. Plant and Soil. https://doi.org/10.1007/s11104-021-04997-8
Gillard et al. 2021. Ecosphere12(5):e03486. https://doi.org/10.1002/ecs2.3486

Biological control of yellow starthistle (*Centaurea solstitialis*)

Yellow starthistle (YST) is among the most costly invasive weeds in western North America, with approximately $1 billion annually lost to control measures and degradation of over 20 million acres of land. In the second half of the 20th century, six insects and one rust pathogen were introduced into the western USA as approved biological control agents, and one additional insect was unintentionally introduced. All these insects attack the YST seed head and the rust infects leaves. All but one of these insects became established but their abundance and impact has been variable, largely according to regional climate types, and widespread control of YST remains incomplete. Following extensive testing for safety by scientists at the ISPH, the weevil *Ceratapion basicorne* was approved for release. The weevil is of particular interest because, unlike other agents, it attacks the root crown of YST. A colony of the weevil has been reared and small numbers these weevils have been released at three sites in California. Monitoring at the sites has not yet confirmed field establishment but scientists remain hopeful that the weevil will soon reach large enough populations to be detectable.

Ceratapion basicorne: The yellow starthistle rosette weevil



Releasing the YST rosette weevil in CA

In an effort to expedite establishment of the weevil throughout the west, a coalition of stakeholder laboratories has been formed by ISPH to coordinate rearing of the weevil in large numbers. Rearing the weevil is a laborious and challenging endeavor.
In addition to *Ceratapion basicorne*, other YST biological control agents are currently under study. Another weevil that attacks the YST seed head, *Larinus filiformis*, and a mite that stunts the growth of rosettes and bolting plants, *Aceria solstitialis*, are currently being tested by ISPH scientists in preparation for release petitions.

Contact: Brian Rector (Brian.Rector@USDA.gov)

Additional reading:

Cristofaro et al. 2013. Biol. Control 64:305; doi:10.1016/j.biocontrol.2012.11.001
Smith & Park 2022. Environ. Entomol. 51:71; doi:10.1093/ee/nvab110
Gütelkin et al. 2008. Environ. Entomol. 37:1185; doi:10.1093/ee/37.5.1185
Stoeva et al. 2012. Exp. Appl. Acarol. 56:43; doi: 10.1007/s10493-011-9497-6

Biological control of arundo (*Arundo donax*) in the Central Valley

Arundo, also known as giant reed, is a perennial grass from Mediterranean Europe that has invaded riparian habitats (shorelines of rivers, canals and lakes) in California, including the Sacramento and San Joaquin River watersheds that comprise the Delta. Arundo consumes and wastes water, blocks flood control channels, increases erosion, fuels wildfires, and displaces native plants and animals. Chemical and mechanical control are widely used but expensive (over $70 million spent in California alone) and do not provide long-term control. USDA-ARS scientists in California and Texas tested biological control agents from the native range and released two in the Lower Rio Grande Basin of Texas and Mexico. Both agents established large populations, reducing arundo biomass and shoot density by over 50%. Scientists from the ISPH released these biocontrol agents at 11 sites in northern California beginning in 2017.

Biological control agents released against arundo in California. Left to right: The shoot tip-galling wasp *Tetramesa romana*; Dead shoot tip with exit holes; The root- and shoot-feeding armored scale *Rhizaspidiotus donacis*; Side shoot distorted due to scale.

Collection of samples to examine for damage by arundo agents

Establishment of the wasp *Tetramesa romana* was confirmed at eight sites in the Central Valley by counting exit holes made by emerging adult wasps, trapping adults on sticky traps, and dissecting samples. The armored scale is established at nine sites. Scales were found in dense populations at the bases of side shoots, in some cases causing shoot distortion. The wasp has dispersed up to 4 miles (6.4 km) following release. The impact these insects have on growth and survival of arundo is under investigation. In addition, a third agent, a leaf-mining fly, is under evaluation in the ISPH quarantine lab.

Contact: Patrick Moran (Patrick.Moran@USDA.gov)

Additional reading:

Goolsby et al. 2023. Inv. Plant Sci. Manage. 16: 81-109. https://doi.org/10.1017/inp.2023.17
Bitume et al. 2024. Biol. Cont. 105489. https://doi.org/10.1016/j.biocontrol.2024.105489.

Biological control of Cape-ivy (*Delairea odorata*) along the California coast

Cape-ivy (*Delairea odorata*) is a perennial vine in the sunflower family from South Africa that has invaded tens of thousands of acres along the California coast and coastal mountain valleys. Cape-ivy smothers other vegetation and obstructs water flow in coastal streams. Dead vines provide fuel for wildfires. At least 56 threatened or endangered species are at risk in California's biodiverse coastal ecosystems. Chemical, physical and mechanical control is widely practiced but it is expensive, causes collateral damage to native plants and does not provide long-term control. USDA-ARS scientists from the ISPH discovered and tested biological control agents in Cape-ivy's native range. Since 2017, a shoot-tip galling fly has been released at 18 sites along the California coast, including at several state parks.

The shoot tip-galling fly *Parafreutreta regalis* is the first biological control agent released against Cape-ivy. Left: Adult fly, about 3x magnified. Center: Galled Cape-ivy shoot tip with exit hole on left gall. Right: Cage used to initially release flies at sites.

We are happy to report that the shoot tip-galling fly *Parafreutreta regalis* is established at 13 sites along the California coast. Galls were found from several feet to 4 miles from the original release point at each site. Gall densities increased up to three-fold over prior surveys at some sites, with highest densities in the fall. The impact of these galls is being evaluated by comparing plant biodiversity before and after releases. Changes in Cape-ivy shoot and flower density, as well as fall biomass, are being evaluated as well. Studies to determine the ability of the fly to limit regrowth after herbicide application began at a California State Park during 2023. A permit application to release a second agent, a leaf- and stem-mining moth, is pending. This moth may be able to establish in cool, shady conditions that are less-preferred by the fly.

Contact: Patrick Moran (Patrick.Moran@USDA.gov)

Additional reading:

Portman et al. 2021. Biol. Cont. 156: 104555. https://doi.org/10.1016/j.biocontrol.2021.104555
Mehelis et al. 2015. Environ. Entomol. 44: 260-276. https://doi.org/10.1093/ee/nvu030

Biological control of bagrada bug (*Bagrada hilaris*)

Bagrada bug (top) and *G. aetherium* (bottom)

Bagrada bug, *Bagrada hilaris*, is an invasive stinkbug pest of cruciferous crops (broccoli, cauliflower, kale, arugula, etc). Originally from southern Asia, it was discovered near Los Angeles in 2008, and has since spread throughout the crop growing areas of California and eastwards into Arizona, New Mexico and Texas. It is unique among stinkbugs in that it buries its eggs in soil.

In surveys from 2017-19 we found high predation rates on bagrada bug eggs but very low parasitism (< 1%). However, in 2020 we discovered the parasitoid *Gryon aetherium* attacking bagrada bug eggs at a site in California. It is unknown how the parasitoid arrived in California and it is likely from the native range of bagrada bug in Asia. In fall 2021-22 we monitored parasitism by *G. aetherium* on bagrada bug eggs at several sites in California, including the Salinas Valley where most cruciferous crops in the United States are grown. We placed soil-filled trays under infested plants for one to two weeks, then removed eggs and held them for emergence of parasitoids.

Gryon aetherium accounted for over 99% of the parasitoids, and occurred at 11 of the 12 sampled sites, whereas the native parasitoid *Ooencyrtus californicus* accounted for < 1% of egg parasitism. Nearly fifty thousand *B. hilaris* eggs were collected in 2021-22 but only 9% were parasitized by *G. aetherium*. Parasitism rates were generally higher inland and reached a maximum of about 45% in 2021 and 23% in 2022, but never exceeded 15% at several coastal sites in the Salinas Valley. *Gryon aetherium* is likely to play a role in regulating *B. hilaris* populations, particularly in warmer inland areas, and appears to be able to locate egg patches efficiently. A series of laboratory experiments showed that *G. aetherium* is capable of finding and attacking eggs buried in soil, while *O. californicus* is not, and that the inability of *O. californicus* to forage in soil likely limits negative interactions between these two species.

A field site (left), a Petri dish filled with soil (center) and a Petri dish under an infested host plant in the field (dishes were covered with cardboard covers to provide shade).

Contact: Brian Hogg (Brian.Hogg@USDA.gov)

Additional reading:

Hogg et al. 2023. J. Econ. Ent. 116(5):1540–1550. https://doi.org/10.1093/jee/toad172
Hogg et al. 2022. Biol. Cont. 171: 104942. https://doi.org/10.1016/j.biocontrol.2022.104942

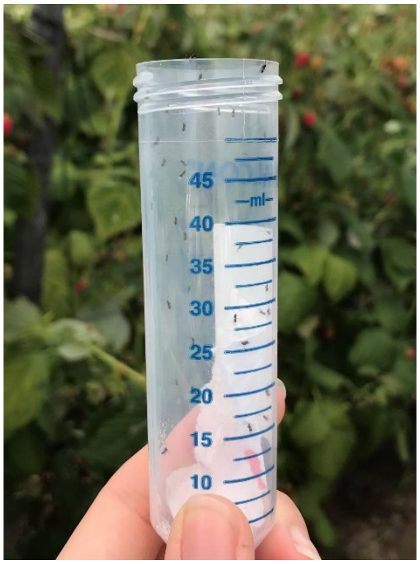
Biological control of spotted wing drosophila (*Drosophila suzukii*)

Spotted wing drosophila (top) and *G. brasiliensis* (bottom)

Spotted wing drosophila (SWD) is a devastating pest of small fruits and cherries. SWD develops on wild and ornamental species in the surrounding landscape, and areawide tools such as biological control are needed for long-term suppression. No naturally occurring parasitoids in North America can consistently attack SWD larvae. Consequently, researchers explored Asia for specialized parasitoids of SWD larvae. Of the three parasitoid species evaluated in quarantine, *Ganaspis brasiliensis* was the optimal parasitoid based on its specificity and performance.

In 2022, we released *G. brasiliensis* for the first time in California in coordination with UC Berkeley collaborators. Releases occurred at a site in Santa Cruz County, CA, which was paired with a control site a few miles away where no releases took place. Sites were approximately the same size and consisted of non-crop habitat infested with wild blackberry bordering raspberry and blackberry fields. Wild blackberries are a widespread host of SWD that likely contributes to the pest's populations. Cooperating research groups ran companion studies at paired sites in Oregon and Washington.

A total of ~1500 *G. brasiliensis* were released at the California release site on seven dates in 2022 and ~2300 were released on eight dates in 2023. In 2023, releases were expanded to four additional sites in Santa Cruz, two in Monterey County, and one each in Ventura and Fresno counties. Thus far, *G. brasiliensis* has been recovered at two sites, mainly in wild blackberries bordering berry crop fields.



Releasing parasitoids (left) and *Ganaspis brasiliensis* escaping from a vial (right).

Contact: Brian Hogg (Brian.Hogg@USDA.gov)
Additional reading:
Daane et al. 2021. J. Pest Sci. 94: 1171-1182. https://doi.org/10.1007/s10340-021-01368-1
Hougardy et al. 2022. Environ. Ent. 51(6): 1106-1112. https://doi.org/10.1093/ee/nvac083

Biological control of invasive annual grasses

Several annual grass species of Eurasian origin, including cheatgrass (*Anisantha tectorum*), red brome (*Anisantha rubens*), medusahead (*Taeniatherum caput-medusae*), and wiregrass (*Ventenata dubia*), have become invasive in western North America, where they are associated with the recent increases in the frequency and intensity of wildfires. Native range surveys of annual grass populations by ISPH and in-country collaborators have revealed the following candidate biological control agents to date: On cheatgrass, a mite species (*Aculodes marcelli*), two gall midges (*Stenodiplosis tectori* on seeds and *Mayetiola bromi* in the crown), a seed weevil (*Pachytychius* sp.), a rust fungus (order Pucciniales) and one other fungal pathogen have been collected. On medusahead, a mite (*A. altamurgiensis*) and a gall wasp (*Tetramesa amica*) have been discovered. Some pre-release biological studies have been carried out on the two mite species, while testing of the other candidate biological control agents on these two invasive grasses is planned, beginning in 2024. The candidate agents from cheatgrass will also be tested on its progeny species, red brome. Surveys of wiregrass have been limited to date and will focus on central Europe. Additional native range surveys for new candidate agents are needed.

The weevil *Pachytychius* sp., on a cheatgrass spike.

Pupa of the midge *Mayetiola bromi* in a cheatgrass crown gall

Unknown rust fungus on cheatgrass

Contact: Brian Rector (Brian.Rector@USDA.gov)

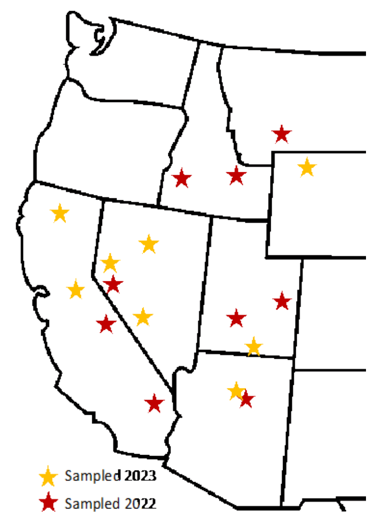
Additional reading:

Vidovic et al. 2022. Insects 13:877. https://doi.org/doi:10.3390/insects13100877
Rector et al. 2021. Insects 12:755. https://doi.org/doi:10.3390/insects12080755
De Lillo et al. 2018. Sys. Appl. Acarol. 23:1217. https://doi.org/doi:10.11158/saa.23.7.1
Lotfalizadeh et al. 2020. ZooKeys 1035:113. https://doi.org/doi 10.3897/zookeys.1005.56353

Mechanisms of plant-microbe interactions in cheatgrass invasion

Invasive exotic weeds occupy tens of millions of hectares of rangeland, forest, wetland and associated riparian ecosystems. Weeds threaten biodiversity and reduce availability and quality of water and soil resources, costing over $7B per year. In the western US, cheatgrass (*Anisantha tectorum*) is the most widespread invasive grass species. Cheatgrass has a host of negative effects on ecosystems: it is a low-quality forage for livestock and wildlife, shortens established fire regimes and increases fire risks, decreases carbon storage in soils, and negatively affects biodiversity. Due to the scope of the invasion, control of cheatgrass with chemical herbicides is not a feasible option for ecosystem-wide management; biological control using microbes is a promising option for long-term control. Currently available strains of bacteria used in cheatgrass biocontrol, such as *Pseudomonas* strains (e.g., ACK55, D7) have shown uneven results in field trials, with highly successful treatment in some locations but not others. One reason for this inconsistent response could be negative interactions between ACK55 and the resident soil microbial community (microbiome).

Soil sampling of squirreltail and cheatgrass in close proximity. Total DNA will be extracted, and the microbiome associated with both plant species will be determined using molecular methods.



Spatial sampling of the rhizosphere microbiome across seven western states.

To gain an understanding of how cheatgrass invasion alters the microbiome, we sampled squirreltail (*Elymus elymoides*), a native perennial grass, and cheatgrass across a range of cheatgrass-invaded sites (see map). We are using molecular methods to determine changes in the taxonomic and functional composition of the soil microbiome. Our initial surveys used targeted sequencing of marker genes (metabarcoding) to identify shifts in diversity, community composition and taxonomy.

We completed two years of broad-scale sampling of the rhizosphere of pairs of squirreltail and cheatgrass across seven states. We have completed targeted sequencing (metabarcoding) of 14 sites across the 2022-23 sampling time points with additional sequencing from 2023 to be completed in 2024. Planned future analyses include shotgun metagenomic sequencing to examine changes in not only the taxonomic, but also the functional makeup of the microbiome.

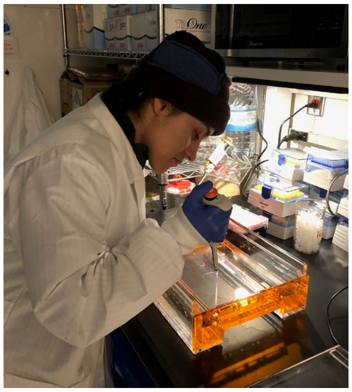
Contact: Rebecca Mueller (Rebecca.Mueller@USDA.gov)

Additional reading:

Reinhart et al. 2020. Range. Eco. & Manage. 73:760-5. https://doi.org/10.1016/j.rama.2019.07.006

Using molecular tools to characterize bioherbicide bacteria

Pseudomonas strains have been used in a wide range of biological control applications, for control of both phytopathogens and invasive grasses such as green foxtail, medusahead and cheatgrass; however, the establishment of commercial strains has been patchy in the natural environment. One possible driver is limited environmental tolerance of existing strains (e.g., the bioherbicide strains ACK55 and D7) in locations spatially distant from the site where the bacteria was originally collected. By culturing novel *Pseudomonas* strains across a range of environments, we can increase the likelihood that the biological control bacteria will establish within the target site, which in turn will enhance the long-term weed suppressive effects of applications.



Commercial and environmental strains were analyzed using molecular methods, including extracting DNA and sequencing the full-length 16S rRNA gene.

Using selective media, we cultured *Pseudomonas* from cheatgrass and squirreltail rhizosphere soils sampled across seven states and 20 sites in 2023, for a total of 40 isolates. We extracted DNA, conducted PCR and sequenced the full-length 16S rRNA gene, a widely used marker for bacteria, for publicly available isolates and *Pseudomonas* cultured from environmental samples. Initial analyses indicate that neither ACK55 nor D7 are *P. fluorescens*, but more closely related to *P. salomonii*. The two strains also show high levels of similarity (99%) across the 16S. High molecular weight DNA has been extracted from ACK55 and D7 and will be submitted for whole-genome sequencing following additional quality controls.

We are currently conducting laboratory trials to determine whether environmental isolates act as bioherbicides for cheatgrass seeds. Initial analysis on bare seeds from three sites using high densities of bacterial cells indicated that all environmental isolates, plus the ACK55 and D7 commercialized strains, inhibit cheatgrass germination, and a subset of seeds showed evidence of bleaching and disease (black spots). Subsequent trials will scale to include sterile media (sand and potting soil) and field soil to determine the effects of physical barriers, seed source and microbial competitive interactions on the efficacy of all *Pseudomonas* environmental strains, tested against ACK55 and D7 strains and negative controls (water addition).

Cheatgrass seeds from Arizona grown with and without the addition of *Pseudomonas* isolated from local soils.

Contact: Rebecca Mueller
(Rebecca.Mueller@USDA.gov)

Additional reading:

Walsh et al. 2001. Cur. Opin. Biotech.12:289-95. https://doi.org/10.1016/S0958-1669(00)00212-3
Kennedy 2018. Biological Control 123:18-27. https://doi.org/10.1016/j.biocontrol.2018.05.002

Biological control of gorse (*Ulex europaeus*)

Gorse, *Ulex europaeus*, is an invasive exotic shrub that infests pastures, rangeland, and wildlands in the coastal counties of California. It grows into large bushes that are very spiney and become impenetrable. Gorse infestations increase fire hazards, interfere with recreation, limit access to natural areas, increase control costs in rights-of-way, and remove land from grazing.

Previously, two exotic natural enemies have been introduced as biological control agents: the seed weevil, *Exapion ulicis* (Forster) (Coleoptera: Apionidae), released in 1953, and the beneficial spider mite, *Tetranychus lintearius* Dufour (Acari: Tetranychidae), released in 1994. Both agents established and are now widespread. In 2019, a third biological control agent, the beneficial thrips, *Sericothrips staphylinus*, was approved for release in North America.

Gorse thrips, *Sercothrips staphylinus*. Photo: *Thrips*-ID

Adult and nymphal feeding damage gorse stems by piercing and removing the contents of leaf and stem cells, thereby stressing the plant and reducing its growth rate. Initial releases of this thrips were made in coastal regions of Oregon by Joel Price of the Oregon State Department of Agriculture. We acquired a colony from Joel and started a colony at the ISPH lab for releases in California. Thus far, the thrips has been released in the California counties of Marin, San Mateo, Mendocino, and Humboldt.

Only limited evidence of thrips activity was seen at sites where a few thrips were recovered on the release plants. No evidence of thrips or thrips feeding activity were found at the other release sites but, that is not unusual when thrips populations are low in abundance. All release sites will continue to be monitored for the next few years. We hope that thrips will become abundant at these release sites so individuals can be collected and redistributed to other gorse infested areas.

Feeding damage by gorse thrips. Left: healthy, undamaged stem; Right: stem with feeding damage. Photo: Joel Price, ODA

Contact: Paul Pratt (Paul.Pratt@USDA.gov)

Additional reading:

Price, J. 2020. https://gorseactiongroup.org/oregon-begins-2020-gorse-control-efforts-using-newly-permitted-gorse-thrips-sericothrips-staphylinus/

Future biological control of crystalline ice plant in California

Crystalline ice plant (*Mesembryanthemum crystallinum*) and slenderleaf ice plant (*Mesembryanthemum nodiflorum*), native to western South Africa, are annual plants that have invaded the Channel Islands off the coast of southern California and the Baja Peninsula and associated islands in Mexico. They salinize and degrade the soil, displacing native plants and animals and hindering restoration projects. Chemical or mechanical control are difficult or impossible in these sensitive habitats. We initiated a biological control project in 2021 by investigating the genetic area of origin of the invasive populations and exploring the native range for biological control candidates.

Invasive ice plants. From left: Crystalline ice plant (*Mesembryanthemum crystallinum*); Slenderleaf ice plant, *Mesembryanthemum nodiflorum*; Large invasive populations of both species on one of the Channel Islands; Map showing sampling at 27 sites.

Samples from 27 sites were collected from 7 of the 8 U.S. Channel Islands and five Mexican Channel Islands, as well as from the mainland of both countries. Analysis of DNA from the samples is being conducted by a collaborator at Rhodes University in South Africa in comparison to samples from there and from the Mediterranean Basin where the ice plants are also invasive. The results so far indicate a possible near-term origin in the Canary Islands off the coast of Morocco, with western coastal South Africa as the original source. Explorations in South Africa on crystalline ice plant have found a stem-boring weevil (*Lixus carinerostris*). It has been imported into the ISPH quarantine lab for host range testing. Explorations in the Canary Islands by a collaborator found a root-feeding weevil (*Temnorhinus mixtus*) as a potential candidate agent against slenderleaf ice plant. We are planning additional foreign surveys for 2024.

Candidate agents of ice plants. Left, the stem-boring weevil *Lixus carinerostris* in south Africa on crystalline ice plant. Center, larval damage and pupal case of the root-feeding weevil *Temnorhinus mixtus*, found in the Canary Islands (part of Spain) on slenderleaf ice plant. Right, adult of this weevil.

Contact: Patrick Moran (Patrick.Moran@USDA.gov)

Classical biological control of Russian thistle (*Salsola* spp.)

Tumbleweeds (*Salsola* spp.) are widespread and damaging Eurasian invasive weeds in the western USA, invading arid natural areas, displacing native plants and wildlife, and hindering grazing by livestock. They are an important weed in spring wheat and other arid fallow and conservation tillage crops and also act as off-season "reservoirs" for several pests of fruit and vegetable crops. Dead plants spread seed by their characteristic "tumbling," and can clog irrigation canals, pile up on fences, and create hazards on roadways. At least six introduced tumbleweed species are invasive in the western USA: *Salsola tragus*, *S. australis*, *S. collina*, *S. paulsenii*, *S. ryanii*, and *S. gobicola*. In the 1970s, two moth species, *Coleoptora klimeshiella* and *C. parthenica* were released as approved biocontrol agents but they have not provided widespread control. A mite, *Aceria salsolae*, was tested by the ISPH and a petition for its release is expected to be approved in 2024. In addition, a defoliating and seed-feeding moth, *Gymnancyla canella*, is currently being tested in the ISPH quarantine laboratory in preparation for a release petition. Additional native range surveys for new candidate biological control agents are needed.

A tumbleweed plant with seeds damaged by *Gymnancyla canella* in the native range (France).

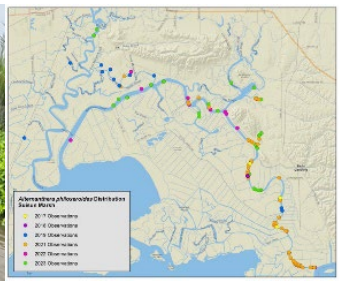
Contact: Brian Rector (Brian.Rector@USDA.gov)

Additional reading:

Marini et al. 2021. Biol. Control 152:104455; https://doi.org/doi: 10.1016/j.biocontrol.2020.104455

Alligator weed (*Alternanthera philoxeroides*): ecology and spread of a recent northern California invasion

Alligator weed, a perennial floating plant that is native to South America, has long been recognized as one of the world's worst aquatic weeds. Invasive populations have persisted in limited areas of California since the 1970s. In 2017, we detected a new invasion in the Suisun Marsh and inland Sacramento-San Joaquin Delta. Chromosome and genetic evaluations revealed it to be an independent introduction of a rare haplotype distinct from historic populations in California, and all but one other known population in southern Georgia. Limited observations suggest it is somewhat salt tolerant, yet it has presumed to be limited to freshwater. Sea level rise is increasing in the invaded estuary, yet the environmental tolerances and capacity of this haplotype for invasive spread with salinity intrusion from sea level rise were unknown.



We conducted a field study to increase knowledge of the phenology and ecology of the alligator weed haplotype, provide science-based support management including biological control, and to track its invasive spread in Suisun Marsh where its management has not commenced. From 2017 to 2023, occupied patches in the Suisun Marsh study area increased by 98%. GPS-based mapping of the weed distribution was used to select 18 stratified random patches, including 6 replicates in upper-, mid- and lower-bayward tidal reaches, for detailed study along a salinity gradient. Interannual distribution mapping was repeated in 2021-23, noting persistent, new, and extinct patch locations. In 2021-2023, the total occupied area of the study patches increased by 37%. The greatest increases in population size were in both the more saline upper reach and the freshest bayward reach, while interannual patch extinction due to breakage and dispersal was common in the mid-tidal reach.

In 2022, two full factorial greenhouse experiments were conducted to evaluate salinity level effects of 1) free-floating and 2) soil-anchored emergent growth forms of alligator weed at the whole plant level (growth, biomass production and allocation, fitness), and for physiological and biochemical plant trait responses that can contribute to salinity tolerance. Pre- and post-harvest measurements were taken; laboratory analyses of plant tissue were completed in 2023. Results from both experiments document alligator weed's sensitivity to increasing aqueous salinity, though all experimental plants survived in freshwater to marine salinity levels. Our results reveal alligator weed's dual strategy to tolerate salinity-induced physiological stress. The weed expressed functional trait responses revealing a stress tolerant strategy, but also responses supporting a stress escape/avoidance strategy.

Contacts: Brenda Grewell (Brenda.Grewell@USDA.gov) and Paul Pratt (Paul.Pratt@USDA.gov)

Additional reading:
Williams et al. 2020. Inv. Plant Sci. Manage. 13(4): 217-225. https://doi.org/10.1017/inp.2020.32

Classical biological control of alligator weed (*Alternanthera philoxeroides*)

Alligator weed, *Alternanthera philoxeroides,* is a semiaquatic perennial plant that is native to South America but invasive in waterways and wet landscapes in many regions of the world. Dense mats formed by the weed in the exotic range negatively affect ecosystem functions and human activities. Alligator weed has historically been an aquatic weed of the southeastern US but a population was discovered in the Sacramento San Juaquin River Delta in 2017. As described above (see page 17), the weed continues to spread throughout sensitive aquatic ecosystems in northern California.

A biological agent from Argentina, the beetle *Agasicles hygrophila,* was introduced into the US over five decades ago and has provided complete control of *A. philoxeroides* in much of the southeastern US but has failed to establish in cooler, more temperate regions like California. Recent research to identify cold-adapted populations of *A. hygrophila* culminated in the discovery of a new Argentine biotype that is more cold-tolerant than populations currently established in North America. The host specificity and environmental safety of *A. hygrophila* is well established. Scientists in 3 countries tested approximately 95 plant species in host range studies from the early 1960s through the early 1980s and determined that *A. hygrophila* was sufficiently host specific for release in their respective regions.

In 2023, we studied the host range of this new cold-adapted biotype of *A. hygrophila* by presenting it with critical plant species that are close relatives to alligator weed. No-choice larval development as well as multiple-choice and adult oviposition tests confirm that this new *A. hygrophila* biotype is host-specific to alligator weed. Under no-choice conditions, *A. hygrophila* larvae only fed and completed development on *A. philoxeroides*. Larvae did not develop past the first instar stage on any non-target plant species tested. Collectively, these data indicate that the new biotype of *A. hygrophila* shares the same narrow host range as the biotype originally approved and established in the USA since 1964. We have prepared a petition to release this new cold-adapted biotype of *A. hygrophila*, which will be submitted to federal regulators in early 2024.

Contacts: Paul Pratt (Paul.Pratt@USDA.gov) and Brenda Grewell (Brenda.Grewell@USDA.gov)

Additional reading:

Knight et al. 2023. Ent. Exp. App. 171(12):1019-1033. https://doi.org/10.1111/eea.13301
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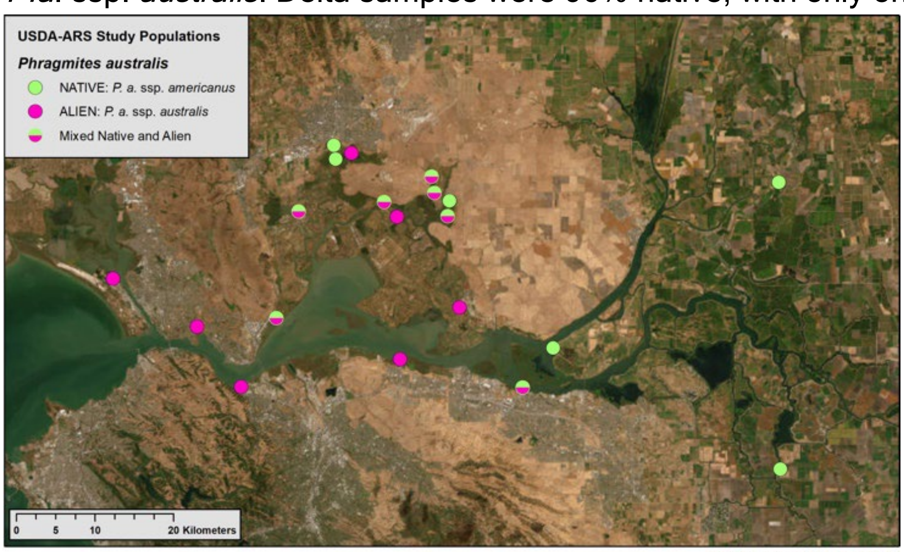
Common reed (*Phragmites australis*): genetic study clarifies identity of populations in California's San Francisco Bay-Delta Estuary

Accurate taxonomic identification of weed species is the essential first step towards understanding invasions and developing effective integrated weed management strategies. Native and alien lineages of the tall wetland grass *Phragmites australis* co-occur in a wide range of wetlands. *P. australis* invasions have been intensively studied elsewhere in the US, but distribution of the lineages in northern California has been uncertain and taxonomic keys do not universally apply. Non-native *P. a.* subsp. *australis* and hybrids are highly invasive in disturbed habitats, displace native *P.a.* ssp. *americanus,* and reduce native fish and wildlife habitat. The native taxa has been present in the US for at least 40,000 years, and macrofossil evidence confirms its presence in the Sacramento-San Joaquin Delta – Suisun Marsh for nearly 4,000 years, concurrent with formation of the estuary's tidal wetlands following the past ice age. The native provides ecosystem services supporting biological diversity, and can serve as a wetland foundation species to stabilize sediments and raise marsh elevations for restoration of subsided wetlands facing sea level rise.

To clarify distributions of *Phragmites* lineages in the study region, we sampled plots within 20 common reed populations in the Delta, Suisun March (focal area), and sites downstream to the Napa River. To differentiate lineages, we used molecular, morphometric and biochemical trait evaluations and completed initial analyses of 400 plant samples. With our collaborator John Gaskin (USDA, Sidney, MT) we used nuclear microsatellite markers, restriction site analysis, and Baysian clustering to identify native, alien or hybrid status and genotypes of all samples. No hybrids were detected. Overall, 42% of our samples were native *P.a.* ssp. *americanus* and 57% were alien ssp. *P.a*. ssp. *australis*. Delta samples were 96% native, with only one dominantly native but mixed population in fringing wetland along the San Joaquin River. We found 62% of samples from Suisun Marsh were the alien taxa, but native stands (38%) were extensive in fringing marsh along tidal sloughs and in relict tidal marsh plains. Alien taxa were primarily in diked wetlands with altered hydrological regimes. The alien taxa appears to be displacing historic native stands in mixed populations along northern Suisun Marsh tidal sloughs. Samples from south Suisun Bay, Carquinez Strait and a Napa River restoration wetland were 100% alien *P. a.* ssp. *australis*. Further evaluations of data are underway to develop observation-based identification tools to support targeted management of the non-native weed, wetland restoration, and conservation of native *P. a.* ssp. *americanus.*



USDA-ARS Grewell et al. 2023

Contact: Brenda Grewell (Brenda.Grewell@USDA.gov)

Classical biological control of Scotch broom (*Cytisus scoparius*)

Scotch broom is a widely distributed weed in the western US, particularly along roadsides and disturbed forest clearings. Two biological control agents were introduced in California in the 1960s: *Exapion fuscirostre* (a seed weevil, Coleoptera: Brentidae) and *Leucoptera spartifoliella* (a stem-mining moth, Lepidoptera: Lyonetiidae). While both agents established and are now widespread, neither has caused the amount of damage sufficient to reduce broom populations. The seed feeding weevil *Bruchidius villosus* (Coleoptera: Chrysomelidae) was released in Oregon and Washington and eventually dispersed to California. Its abundance is variable, but it attacks up to 87% of seeds and may have some impact on broom populations.

Recently, a gall mite, *Aceria genistae*, was discovered infesting broom plants in the western US, including California. An individual mite is very small, barely visible to the naked eye but despite their small size, their feeding damage is very noticeable. Mites attack Scotch broom buds, their feeding stimulates the development of small fuzzy galls that occur along the length of a stem and can become quite numerous on a single plant. The mites feed within these galls, and many believe the gall provides a safe haven from predators.

The Scotch broom gall mite is well known in the biological control community: it was tested and considered safe for release in New Zealand in 2007 and Australia in 2008. Because the gall mite arrived in the western United States by unknown means, there is currently no permit to move or redistribute it locally. We are actively conducting host specificity testing in the lab and monitoring native plants that are close relatives to Scotch broom for gall formation in the field. These data will be used to support a petition to federal and state regulators for approval to redistribute the mite to other areas.

As these pictures indicate, gall development dramatically alters plant architecture but these galls also reduce seed production. One of our recent studies indicates that heavily galled large plants produced up to 80% fewer seeds than lightly galled plants of a similar size. We suspect that the present impacts of the Scotch broom gall mite is an omen of greater things to come, with additional effects to plant survival still to be realized as the mite continues to spread.

Contact: Paul Pratt (Paul.Pratt@USDA.gov)

Additional reading:

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Sarratt et al. 2023. Biocont. Sci. Tech. https://doi.org/10.1080/09583157.2023.2245984

Future biological control of stinkwort (*Dittrichia graveolens*) in California

Stinkwort (*Dittrichia graveolens*), native to the Mediterranean Basin, is an invasive annual herb or small shrub in the sunflower family that was first detected in the U.S. in the San Francisco Bay Area in the early 1980s and has since spread to 49 of California's 58 counties. This weed invades disturbed areas, crop fields, orchards and vineyards and thrives especially in dried-out water ponds. It has potential to invade forests and grasslands and is spreading northward and into the Sierra, with potential to invade other states. We initiated a biological control project targeting stinkwort in 2021, in collaboration with the European Biological Control Laboratory (EBCL) in Montpellier, France. The first steps are to determine the invasive origin of the populations in California, and to explore the native range for insects that could be good candidates as biological control agents.

Stinkwort in California. Left, population in summer near Davis, CA. In summer, stinkwort looks superficially like Russian thistle. Middle, stinkwort in fall near San Diego, CA. The 'puffballs' (seedheads) make stinkwort easy to spot in the fall. Right, sampling for genetic origin studies covered 25 sites in California.

We sampled hundreds of leaves and seedheads across 25 California sites from Redding to San Diego. All sites were in disturbed areas such as roadsides and near agricultural fields. DNA from the samples is being analyzed for genetic diversity by a scientist at the EBCL. Another scientist there has discovered a moth in Greece and Cyprus that can remove up to 80% of the leaves on plants in late summer. The ISPH is providing seeds of close relative plants to colleagues at the EBCL to facilitate host range tests that are planned for 2024.

Candidate biological control agent of stinkwort, the moth *Condica viscosa*. Left. Larva (magnified about 4x). Center: Adult moth. Right: Stinkwort from Cyprus (an island nation in the Mediterranean Sea) defoliated by the moth.

Contact: Patrick Moran (Patrick.Moran@USDA.gov)

Long-term monitoring and potential impacts of climate change on honey bees

A HACU intern, Laneia Pozzesi, conducting monthly detailed assessments to assess colony health and strength.

Long-term honey bee health monitoring is critical for understanding how environmental factors such as pollination services, climate, and weather patterns interact with more immediate stressors such as diseases and poor nutrition that might result in a severe decline in honey bee health. To date, we have established a long-term honey bee health monitoring program with three beekeepers around the Davis, California area that has been ongoing for two years. Parts of these data are under analysis, even as monitoring continues for the 3rd and 4th years. Colonies were monitored for colony survival, strength, food resources, and diseases. Queens were replaced each year to follow commercial beekeeping practice and queen quality analyses were completed. We found that pollination services of almond crops had a net positive effect on colony food stores and size, while sunflower crops increased colony food stores as well as reduced disease loads, increasing the survival of the colonies. Overall pollination services provided by the honey bees are a win-win for crop production, honey bee health, and colony strength.

Given the large wildfires due to climate change in California in 2020 and 2021, we completed studies on the impact of poor air quality and high ambient temperatures on bee health using extensions of the monitoring program. This study was undertaken at the request of beekeepers. Poor air quality and higher temperatures, resulting from ongoing changes to the climate, which are predicted to worsen in the future, are related to additional stress in honey bee colonies, the colonies are weaker from reduced immune functioning resulting in them being more prone to obtaining infections, at higher levels, weakening honey bee colonies even more. This study also led to a method where we could evaluate the health of honey bees by examining key glands that are used to feed developing honey bees and using this as a general biomarker of health status. In the future, we will continue to develop and expand our longitudinal monitoring efforts to evaluate relative benefits of new management discoveries to improve honey bee health.

Contact: Chris Mayack (Christopher.Mayack@USDA.gov)

Additional reading:

Mayack et al. 2023. Insects14: 689. doi:10.3390/insects14080689
Cook et al. 2023. J. Vet. Diagn. Invest. 35: 630-638. doi:10.1177/10406387231191732.
Arathi and Smith. 2023. Ecology and Evolution 13: e10324. doi.org/10.1002/ece3.10324

Nutritional impacts on honey bee health from different pollen sources

To increase food productivity so that it is readily available for a growing world population, we are reliant upon honey bees for their pollination services to produce the fruits, nuts, and vegetables that we eat on a regular basis. Therefore, throughout California, a top food producing state in the nation, honey bee colonies are placed in orchards and crops for their pollination services to increase the yield of these crops. However, this means that during this time honey bees are largely reliant upon a single food source that may have potential negative impacts on honey bee health.

We found that different pollen types that varied in their availability throughout the year exhibited significant differences in vitamin and mineral profiles that are essential for carrying out life activities and maintaining optimal health. Although honey bees may be getting enough protein and lipids from a singular crop pollen source, our findings suggest that a diverse diet of different pollen types is important for the honey bee to achieve optimal health and that the planting of different floral resources in and around crops and orchards is likely to have a positive impact on honey bee health. In addition, there are a variety of beneficial chemicals that are produced from plants that are intended to protect the plants from herbivores that eat them, such as caffeine and p-coumaric acid. We are currently researching the potential positive and negative effects of these phytochemicals on honey bee health in terms of queen egg laying, longevity, disease loads, and the physiology of the bee. Consumption of these chemicals should be another aspect to contemplate when considering access to pollen diversity and what the possible impacts might be for improving honey bee health.

Contact: Chris Mayack (Christopher.Mayack@USDA.gov)

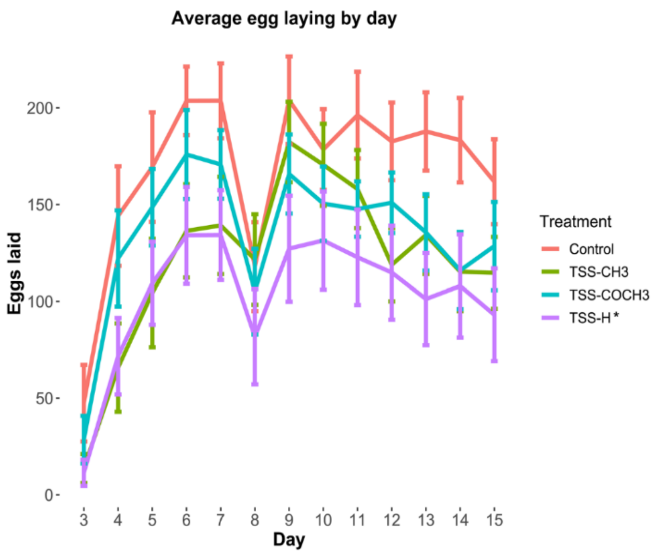
Additional reading:
Bernklau & Arathi. 2023. J. Econ. Entomol. 116: 1069-1077. DOI: 10.1093/jee/toad096

Colonies providing pollination services in almond orchards that are being studied as part of the long-term honey bee health monitoring network.

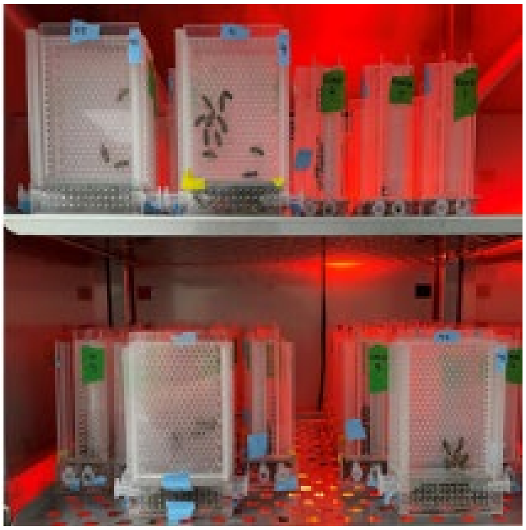
A surfactant decreases egg laying and increases virus in worker honey bees

Surfactant adjuvants are commonly added to pesticide tank mixes to increase the penetration and spread of active ingredients that are applied in various cropping systems to control pest insects. A class of adjuvants known as trisiloxane surfactants (TSSs) can persist in hives (such as in collected pollen) at surprisingly high rates (up to 40.4 parts per million), suggesting that TSS exposure presents a risk to all members of a honey bee colony. Previous work has demonstrated TSSs can impair the immune system of larval honey bees, leading to increased rates of death. However, until recently, the effects of TSSs on queens and workers remained relatively unexplored.

We collaborated with ARS scientists in Logan, UT and Baton Rouge, LA as well as Utah State University to investigate how a field relevant dose of various TSSs in pollen diet (5 ppm) affects queen egg laying and viral pathogen replication in worker honey bees. We found that queens exposed to a particular TSS through the diet of their worker caretakers laid fewer eggs. Similarly, when workers consumed a pollen diet laced with a different TSS, we detected higher levels of deformed wing virus in their bodies, a potentially devastating honey bee pathogen. Taken together, these findings indicate that TSS adjuvants may negatively affect honey bee reproduction and the health of worker bees when they are used in crops that honey bees pollinate, and beekeepers and growers should be aware.



Egg laying over time by queens exposed to 3 different kinds of TSSs compared to a control group. Queens exposed to TSS-H laid significantly fewer eggs than queens in the control group.



Above: Egg laying was monitored in specialized microcolonies kept in an incubator under red light, which bees cannot detect.

Contact: Julia Fine (Julia.Fine@USDA.gov)

Additional reading:

Fine et al. 2017. Sci. Rep. 7 (1): 1-9. https://doi.org/10.1038/srep40499.

Fine et al. 2024 Environ. Toxicol. Chem. 43 (1): 222-233. https://doi.org/10.1002/etc.5771.

Developing bees exposed to insect growth disrupting pesticides are less responsive to queen pheromone

Just like in humans, early stages of honey bee development shapes aspects of their adult biology and behavior. Developmental exposure refers to a scenario in which bees are exposed to agrochemicals as larvae or pupae, and though it isn't well-studied, this type of exposure can potentially influence the health and the performance of various social behaviors by adults that can, in turn, influence the trajectory of the entire colony. Insect growth disruptors (IGDs) are a class of agrochemicals that target pathways associated with growth and reproduction in pest insects. Honey bees can be exposed to IGDs when they are used in the crops that bees pollinate, and high doses are known to cause brood loss. However, many IGDs mimic hormones that regulate important aspects of honey bee behavior, and little is known about their effects on adult behavior when they are developmentally exposed to sublethal doses. We performed an experiment demonstrating that developmental IGD exposure can have an impact on the performance of a critical reproductive behavior by adult honey bees.

Using a specialized technique to rear bees in a controlled, laboratory environment, we exposed honey bee larvae to sublethal doses of IGDs in their food. Once the bees developed into adults, we tested their responses to queen pheromone and found that exposure to insect hormone mimicking IGDs caused bees to be less responsive. Queen pheromone is produced by queens and elicits queen-care behaviors from workers like grooming and feeding of the queen. Queens rely on the performance of these behaviors by workers to be able to focus on producing eggs for the colony. Therefore, a generation of worker bees that are less responsive to queen pheromone could have profoundly negative effects on queen oviposition. Interestingly, the bees exposed to these hormone mimicking IGDs also had altered expression of endocrine related genes in their brains and hypopharyngeal glands, which they use to produce proteinaceous secretions to feed developing larvae and the queen. These shifts indicate that the behavioral changes we observed in IGD exposed bees were driven by physiological changes in critical tissues caused by developmental IGD exposure.

Honey bee workers reared under exposure to IGDs responding to a queen pheromone impregnated lure.

It is worth noting that the doses we used here were higher than what we'd typically expect to see in a colony following IGD use, but it's important to consider the potential of IGDs to cause behavioral shifts in honey bees when evaluating their safety to pollinators. We have yet to assess what may be happening in the field or at lower doses, but behavioral and physical shifts in worker bees such as what we observed here could have implications for the longevity of the colony unit.

Contact: Julia Fine (Julia.Fine@USDA.gov)

Additional reading:

Litsey et al. 2021. Front. Ecol. Evol. 9, 627. https://doi.org/10.3389/fevo.2021.729208.
Litsey & Fine 2024. J. Econ. Entomol. toae006. https://doi.org/10.1093/jee/toae006.

In brief:

South American Spongeplant (*Limnobium laevigatum*)

South American spongeplant has been introduced worldwide, likely through the aquarium trade, and is now considered invasive in California's Delta. We studied the plant's phenology and biomass accumulation at several locations in the Delta to aid management decisions. In addition, plants at 8 locations were sampled monthly for a year to learn if the aquatic weed has acquired any natural enemies following its arrival. Data for these projects are being analyzed and results will be made available in the near future. We are also collaborating with colleagues at LSU to determine if the weevil *Bagous lunatoides*, which attacks the southeastern native *Limnobium spongia*, will also feed on *L. laevigatum* as an initial step to evaluating it as a suitable biological control agent for the western USA.

Biological control of pampas grass (*Cortaderia selloana*)

While pampas grass and the closely related jubata grass (*Cortaderia jubata*) are common ornamental plants in the USA, they are also invasive and readily displace native species in environmentally sensitive regions of the west. The biological control community has been reluctant to develop a program targeting these species due to conflicts of interest with homeowners and the ornamental industry. Recently, the seed-feeding midge *Spanolepis selloanae* was discovered by Spanish scientists attacking invasive pampas grass in Europe. This midge lays eggs on flowers and the larvae consume the developing seed, reducing reproduction by as much as 80%. This feeding damage, however, doesn't affect the appearance of plants as the showy inflorescences remain intact. We are acquiring a colony of the midge to begin host range testing in our quarantine facility, with specific interest in learning if the midge will also attack *C. jubata*.

A pathogen for common crupina (*Crupina vulgaris*)

Capable of colonizing a broad range of environments, common crupina is marching across the western USA where it can develop near-solid stands in natural areas and displace other important forage species. The invasive weed is common in Idaho and Oregon but has recently spread into northern California where its distribution is poorly understood. USDA scientists in Maryland and Montana recently released a pathogen, *Ramularia crupinae*, in Idaho and expect to expand releases throughout the west in the coming years. We are working with these scientists to understand how the plant performs under various environmental conditions, in an effort to gather baseline data prior to the pathogen's introduction in California. We welcome your help with recording the presence of common crupina in California and beyond, reach out if you have seen this plant.

Rush skeletonweed (*Chondrilla juncea*) biological control

Rush skeletonweed has been a target of weed biological control for several decades, resulting in the release of multiple agents. However, the weed continues to be a pest because agents are not effective in all areas and for all plant genotypes. We are collaborating with European colleagues to develop additional biological control agents to improve management of the weed, with plans to import two insects into our quarantine facility during the summer of 2024.

Uruguayan Primrose-Willow (*Ludwigia hexapetala*): support for invasion resistant wetland restoration strategies

A restoration plan for the expansive freshwater wetland complex in Russian River watershed's Laguna de Santa Rosa was completed by stakeholders in 2023. Uruguayan primrose-willow, an emergent floating-leaved *Ludwigia* species native to South America, is an aggressive invasive weed that has spread throughout a range of wetland types, reducing biological diversity and impacting other ecosystem services in the Laguna and other wetlands. The shared benefits of weed management and recovery of biological diversity requires revegetation techniques for rapid establishment of wetland plant assemblages that can prevent secondary plant invasions during restoration habitat reconfigurations. Some native plant species persist in the face of the invasion, suggesting the potential for managed biotic resistance in the restoration process. We have intensively sampled and assembled data on the relationship of native species to the weed's abundance and environmental variation. Analyses are underway to identify promising candidates for restoration plantings to be tested in the next steps to evaluate management of community assembly for invasion resistance under climate change and achieve restoration goals.

Water primroses (*Ludwigia peploides*, *L. hexapetala*): Functional traits supporting invasions greatly differ between related species

Understanding functional traits underlying colonization success of invasive plants can be key to developing sustainable management solutions to curtail invasions at the phase when efforts are often most effective. Two *Ludwigia* species (creeping water primrose; Uruguayan primrose-willow) with contrasting biology and ecology have been viewed as the same ("water primroses") by weed managers with largely ineffective control. Using a functional trait response framework in multiple outdoor experiments, we have evaluated growth, physiological and biochemical responses of closely related *Ludwigia* spp. to contrasting environmental conditions when established from asexual fragments. This year we completed an additional field and mesocosm study evaluating species responses to contrasting hydrological conditions. Counter to expectations based on evolutionary differences, *L. peploides* expressed greater trait capacity for flood tolerance while *L. hexapetala* revealed a stress escape strategy at the colonizing life stage. In contrast, longer-established plants in the field revealed a reversed pattern for flood escape versus flood tolerance traits, emphasizing the plants have multiple ways to counter physiological stress that vary with environmental variation and by life stage. Collectively, results support species-specific management approaches with priority for early control of *L. peploides* given its superior colonizing ability.

In the news

Beneficial Wasp May Help Put Sting in Fruit Pest:
https://scientificdiscoveries.ars.usda.gov/explore-our-discoveries/pacific-west/ca-beneficial-wasp-may-help-put-sting-in-fruit-pest

California's Long Term Honey Bee Research Monitoring Network:
https://scientificdiscoveries.ars.usda.gov/ca-californias-long-term-honey-bee-research-monitoring-network

Biocontrol Against a Thirsty Invasive Grass in Arid Regions of the U.S.:
https://tellus.ars.usda.gov/stories/articles/biocontrol-against-thirsty-invasive-grass-arid-regions-us?utm_medium=email&utm_source=govdelivery

isph

INVASIVE SPECIES AND POLLINATOR HEALTH RESEARCH UNIT

2023 Research Publications

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