W3185 Select Cumulative Impacts: 2012-2016

An analysis was completed and published of how weed biological control agents (insects or plant pathogens) can modify weeds in ways that impact other biological control agents, typically those that arrive later in the season. Induced effects of one agent on a weed can result in positive or negative effects on other agents, thus, influencing the net impact of biological control on weeds. Although indirect competition among herbivores created by herbivore-mediated changes in plant quality have been noted in the ecological literature, they have not been studied extensively or applied when making decisions of importing agents in weed biological control programs. In fact, a common assumption is that herbivores that feed on weeds in complementary ways should always improve biological control. However, studies showed that introducing a second weed agent in some cases may *decrease* the overall level of biological control. This research provided a protocol for assisting practitioners in making decisions about whether or when to introduce a second imported agent to assist in the biological control of invasive weeds.

Release of a wasp, the African predator, *Eurytoma erythrinae,* against the erythrina gall wasp, *Quadrastichus erythrinae*, has helped to save the Hawaiian keystone lowland forest tree *Erythrina sandwicensis* from possible extinction.

A comprehensive study determined the return on investment from biological control programs that have targeted the community of invasive pests of Eucalyptus in California. Independent estimates of the total number of eucalypt street trees in California ranged from a high of 476,527 trees (based on tree inventories from 135 California cities) to a low of 190,666 trees (based on 49 tree inventories). Based on a survey of 3,512 trees, the estimated mean value of an individual eucalypt was US$5,978. Thus, the total value of eucalypt street trees in California ranged from more than US$1.0 billion to more than US$2.8 billion. Biological control programs that targeted pests of eucalypts in California have cost US$2,663,097 in extramural grants and University of California salaries. Consequently, the return derived from protecting the value of this resource through the biological control efforts, per dollar expended, ranged from US$1,070 for the high estimated number of trees to US$428 for the lower estimate. The analyses demonstrate both the tremendous value of urban street trees, and the benefits that stem from successful biological control programs aimed at preserving these trees.

The Cuban laurel thrips, *Gynaikothrips ficorum*, is a critical insect pest of *Ficus microcarpa* in California urban landscapes and production nurseries. There have been attempts to establish specialist predator natural enemies of the thrips, but no success had been reported. Areas were resampled where the predator, *Montandoniola confusa* had been released in southern California in 1995 but had been unable to recover individuals in 1997–1998. Thrips galls were significantly reduced in all three of the locations. *M. confusa* was present in all locations and appears to be providing successful biological control. The value of the biological control, the difference between street trees in good foliage condition and trees with poor foliage, was $58,766,166. If thrips damage reduced the foliage to very poor condition, the value of biological control was $73,402,683. Total cost for the project was $61,830. The benefit accrued for every dollar spent on the biological control of the thrips ranged from $950, if the foliage was in poor condition, to

$1,187, if the foliage was in very poor condition. The value of urban forest is often underappreciated.

As an alternative to insecticide sprays harmful to natural enemies, studies demonstrated that trap crops of highly-chemically-attractive *Brassica* varieties can protect broccoli from the crucifer flea beetle.

Work is characterizing dung-beetle biodiversity of west coast organic farms, some of which integrate livestock into their farming operations. Results showed that dung beetles suppress human pathogens in the animal feces they consume.

Research has documented that organic potato farms, where fewer insecticide sprays lead to higher densities of predatory bugs, experience stronger biological control of two-spotted spider mites.

Molecular genetic studies on brown marmorated stink bug indicate that populations from the eastern USA originate from near Beijing and those from the western USA originate from China, Japan and S. Korea. The accidentally introduced parasitoid, *Trissolcus japonicus*, is genetically distinct from populations being studied in quarantine laboratories. *T. japonicus* established in the western USA originated from Japan or Korea whereas the parasitoids in eastern USA do not match any known populations.

Molecular genetic techniques showed that wheat stem sawfly (*Cephus cinctus*) is native to North America, not an invasive alien. Furthermore, there are three genetically distinct populations which indicate local adaptation to wheat which may be a cause of increasing sawfly problems in the southern Great Plains.

The olfactory preferences of the psyllid, *Arytinnis hakani*, for target and non-target weeds were evaluated under laboratory conditions to assess the ecological risks associated with a potential release of this biological control agent in North America.

The parasitoid *Psyttalia lounsburyi* was mass reared and over 58,000 adults were shipped during the past 4 years to California for release to control olive fruit fly (*Bactrocera oleae*).

Our morphological, biological and molecular investigations on the shoot-mining weevil *Mecinus* sp., released for the biological control of toadflaxes, revealed that the weevil species released as *M. janthinus* is actually composed of two cryptic species, *M. janthiniformis* sp. n., which is associated with Dalmatian toadflax and *M. janthinus*, which is associated with yellow toadflax. Monitoring and re-distribution efforts of the two species can now be conducted much more targeted and with a higher likelihood of success.

Work has focused on the importance of natural enemy evenness (equitable relative abundances), an underappreciated and understudied component of biodiversity, for effective biological control. Our applied work has documented the importance of predator, parasitoid and entomopathogen conservation for biological control of pests on pea, potato, *Brassica*, and tree fruit crops.

As an alternative to insecticide sprays harmful to natural enemies, studies have demonstrated that trap crops of highly-chemically-attractive *Brassica* varieties can protect broccoli from the crucifer flea beetle. Additional work has shown that bittersweet nightshade (*Solanum dulcamara*), a plant that harbors potato psyllids (*Bactericera cockerelli*) that vector the zebra chip pathogen of potatoes, also houses diverse communities of predators and pathogens; these natural enemies might decrease the number of potato psyllids migrating to potatoes each year.

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Chalcidoidea are economically and biologically one of the most important groups of insects, and yet very little is known of their taxonomy. 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. This research is providing a better understanding of the wasp parasitoids attacking several pest groups in California including the citrus peelminer, citrus leafminer, sharpshooter parasitoids and the Asian citrus psyllid. 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.

Modules have been developed that explain parasitoids to high school students, Master Gardeners and other venues. The approach is to teach more upper-division students or adults about the importance of parasitoids in biological control. A project is developing 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’ as a means to discuss ‘true’ biodiversity. Our ideas for outreach are being vetted through a broad group of local teachers, and extension researchers at UC Riverside and Texas A&M University.

Eighty one plant species plus several cultivars of economic plants have been undergone no-choice host specificity testing with the crown moth, *Oporopsamma wertheimsteini*. Although the moth appears to be host specific, limited larval development did occur on one native and two exotic species.

From 2012-2016 approximately 89,000 *Aulacidea acroptilonica* were released and established at more than 22 field sites in Montana to combat Russian knapweed. The gall wasp is now established and increasing in population at least eight sites in Montana and recoveries have also been made at 10 additional sites visited in 2016. Consignments were made to CA, CO, ID, NV, OR, and WY.

A biocontrol project against Russian knapweed found that grazing at some field sites significantly decrease the number of *Jaapiella* and *Aulacidea* galls by approximately 83% and 74%, respectively. Rodent feeding on Aulacidea galls was evident at several sites. Predation has now been observed throughout the summer, although more common in mid-autumn. Rodent

feeding was positively associated with the number of galls, although feeding was somewhat patchy within the site perhaps indicating differences in favorable cover for rodents to forage.

The great majority of Reduviidae are predators of other arthropods, but the degree of prey specificity ranges from stenophagous (prey on only specific species of other insects) to euryphagous (feed on many species of insects in a given microhabitat). Species of the diurnal Harpactorinae appear to have the greatest potential as natural enemies; some Reduviidae are also medically important disease vectors. A study has advanced the systematics in this family by taxonomically revising genera, tribes, and subfamilies (including identification keys and distribution maps); revealing phylogenetic relationships at different taxonomic levels from tribes to the entire family; and investigating the natural history of assassin bugs. A new research focus in the lab is to use PCR-based methods to investigate prey range of assassin bugs, including potential natural enemies in California (*Zelus*, *Apiomerus*, and *Phymata*). Miridae comprise plant pests as well as natural enemies.

The USDA-ARS Exotic and Invasive Weeds Research Unit, Albany, CA obtained a biotype of the water hyacinth weevil *Neochetina eichhorniae* from its native range in Uruguay, and from two subtropical areas outside the USA where it has been released (Australia and South Africa). Studies of the temperature tolerance of these biotypes in comparison to the current biotype in California, which is not having sufficient impact, will determine if one of the non-US biotypes is better-suited as a biological control agent of water hyacinth.

The shoot tip-galling fly *Parafreutreta regalis* was released as the first biological control agent in the world targeting the invasive vine known as Cape-ivy (*Delairea odorata*, Asteraceae). Establishment and dispersal of this fly are expected to lead to reductions in the density and spread of Cape-ivy in California.

The planthopper *Megamelus scutellaris* was released by the CA Department of Food and Agriculture and the USDA-ARS for biological control of water hyacinth (*Eichhornia crassipes*) for the first time in California, and establishment was documented. Dispersal of this biocontrol agent is expected to reduce the ability of water hyacinth to clog waterways.

Releases of the arundo wasp in the Lower Rio Grande Basin by collaborators have reduced arundo biomass by up to 44% along the Rio Grande since 2007, saving over 2,000 acre-ft of water in the Rio Grande worth about $1 million annually, while allowing native vegetation diversity to increase two- to three-fold, with potential for substantial additional recovery from the diverse seedbank. Integrated control protocols, consisting of mechanical chopping of arundo shoots followed by biocontrol releases, were shown to be effective in establishing the biocontrol agents, and will reduce arundo control costs and save water.

Studies by the USDA-ARS Exotic and Invasive Weeds Research Unit, Albany, CA, revealed that mechanical damage to yellow starthistle led to production of volatile organic compounds that altered behavior of both generalist (slug) and specialist (insect herbivores, suggesting that plant manipulation of volatile signals may be important in determining the extent of biocontrol damage.

The USDA-ARS Exotic and Invasive Weeds Research Unit in Albany, CA, in collaboration with the University of California-Berkeley, UC-Davis and other institutions, provided educational opportunities for two foreign scientists and scientific training programs for nine students and early career professionals from the U.S. in the theory and practice of biological control of weeds.

The USDA-ARS Cattle Fever Tick Research Laboratory in Edinburg, TX, in collaboration with the University of Texas-Rio Grande Valley, provided educational and scientific research training opportunities for over 25 undergraduate and graduate students in the theory and practice of biological control of weeds.

A large group of scientists collaborated to study the routes of invasion of the pest *Drosophila suzukii*. Evidence was found for 3 separate introductions from native range regions into the introduced range. From Japan to Hawaii, from southeastern China into the western US (mixed also with Hawaiian sources) and from northeastern China into Western Europe (mixed also with US sources). This information is crucial to exploring for biological control agents from the native range. A manuscript is in revision for Molecular Biology and Evolution.

The level of competence of PPQ workers, port inspectors, and customs officials within Micronesia is gradually being raised as more personnel are trained in our annual PPQ workshops. Increased participation by Guam Customs officers appears to reflect heightened awareness of the threat to Guam posed by invasive species and the increased cargo and human traffic resulting from the ongoing military buildup.

Research has indicated the need for increased classical biocontrol programs targeting "legacy" pests infesting perennial tree crops. Legacy pests are non-native insects and are defined as those that have been present in the cropping system for more than 25 years, have not been fully researched for classical biocontrol potential, and are now considered "naturalized" while still causing significant and persistent crop production problems and economic losses.

The host range and host specificity of *Diaphorencyrtus aligarhensis*, a natural enemy of the pestiferous Asian citrus psyllid, and the vector of a lethal citrus disease, huanglongbing (HLB), has now been determined.

The development of a classical biocontrol program targeting the highly pestiferous brown marmorated stink bug in California has been outlined.

Programs designed to learn more about the Asian citrus psyllid (ACP) and associated natural enemies in urban citrus in southern California are showing results. Population dynamics were recorded for 2-3 years across 13 different sites in southern California. These data have provided a solid "snap shot" of ACP and natural enemy population phenology at the initial stages of the classical biocontrol program targeting ACP.

Should coconut rhinoceros beetle (CRB) populations be successfully infested by virulent strains of *Oryctes nudivirus* or *Metarhizium majus*, CRB populations should be reduced to levels that will not seriously impact coconut production on Guam, as is seen currently in Fiji where

successful natural enemies and pathogens have reduced the impact of CRB throughout that island.

Current research projects will contribute to the selection of potentially new biological control agents for the control of noxious weeds. New agents are being investigated for the biological control of Russian knapweed, hoarycress, invasive hawkweeds, and rush skeletonweed. The target weeds have either no biological control agents currently available or the agents already established are not effective over the range of the target weed. In addition, a better understanding of biological control and its implementation will be achieved by monitoring the impacts associated with these biological control agents. In particular the habitat specificity of these arthropods may delineate their potential range or effectiveness.

Significant progress was made in establishing reliable taxonomic information for making identifications of adults and larvae in the large (green lacewing) chrysopid tribes *Chrysopini* and *Leucochrysini*. In addition, a worldwide checklist of natural enemies of *Diaphorina citri* Kuwayama was completed. The results form the underpinnings for future work on the biology, mass production, and use of these predators in biological and integrated pest control programs.

Two species of the *Euwallacea fornicatus* species complex have invaded California and are causing substantial damage to both avocado trees and many native species. Biogeographic work shows that this species complex consists of at least three different species and that two of them have invaded California. The native range of these two species includes Vietnam and Taiwan and we conducted foreign exploration for the natural enemies in Vietnam and Taiwan, where the density of these beetles is substantially lower than in California. Efforts are underway to establish colonies of parasitoids (Bethylidae) in quarantine for further studies to determine the suitability of these wasps for biological control.

Prolonged mass rearing can results in a decline in the field efficacy of biocontrol agents. A large part of ongoing research now deals with the maintenance of the “genetic” quality of the parasitoid for the Asian citrus psyllid *Tamarixia radiata* which is released throughout California for classical biological control. All wasps released in California stem for material originally collected from Pakistan that has been maintained as isofemale lines and is mixed before being mass reared for release. Wasps are only mass reared for a limited number of generations, before new starting material is used, thus avoiding two aspects of prolonged mass rearing: domestication and loss of genetic variation.

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