Response to W5185-Temp Renewal Proposal; Multi-State Collaboration on W4185 Objectives.

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1. Background on multi-state collaborative projects: The most effective way to address new pests that become quickly established and spread to other states is through regional collaboration of state and federal scientists. Experiment Stations and non-Land Grant institution members to this project accrue timely and relevant benefits to participation. Regionality is essential to implementing biological control-based solutions to our pest problems for the following reasons: 1) numerous target pests occur in three or more western states or territories; for these pests, the research effort must be coordinated and duplication minimized to effectively utilize very limited resources; 2) regional importation/quarantine facilities are critical for a coordinated response to exotic arthropod pests and weeds. These facilities are finite, there are no plans to expand them in the foreseeable future, and they serve the needs of all states and territories in the region; and 3) interstate exchange of information and exotic species/biotypes is facilitated through a regional approach. Sharing the cost of foreign exploration and quarantine is essential, as is sharing of methodological advances and our knowledge base. Without a regional project in biological control, the western states and territories will not be able to rapidly share current information on controlling new and existing pest species, many of which have ranges over multiple states. Additionally, this group discusses emerging pest threats and forms collaborations and networks that anticipate and plan for pest arrival. Besides state to state (Experiment Station) collaborations, active participants often include scientists from USDA-ARS, USDA-APHIS, USFS, and state departments of agriculture, all of which benefit from rapid information transfer and shared projects.

Advances in the development of sound ecological theory concerning pest population dynamics, predator-prey interactions, the role of invasion genetics, methodologies for the evaluation and release of natural enemies, and new regulatory policies are all fundamental needs in biological control, along with coordination and cooperation of research for a given pest. For example, theoretical and experimental studies of the actual ecological mechanisms that underpin pest population regulation are being addressed in all participating states and among pest systems. Many of these efforts are addressed through multi-state collaborations and are reflected in the Publication List below. In addition, our members and Federal Advisers, serve on key committees that are steering efforts to minimize non-target effects through policy discussions and recommendations.

Responses to specific questions from the W4185 Renewal Proposal

Are research responsibilities of all participants clearly stated? The research responsibilities of all participants (over 60 in the past 5 years) are found in their submitted Appendices.

Is collaboration and/or interdependence such as the user of common protocols, central data collection or analysis, sharing of equipment, common use of research sample or data, or other evidence of direct collaboration described in the proposal? The use of common protocols is defined in this proposal as the approaches to implementing a successful biocontrol program are enumerated. The collaborative nature of the many projects is reflected in the publication list and in sections below (and on pages 5-6 of the renewal proposal), which also implies the necessity of sharing data. The support for the quarantine facilities is most important to “sharing equipment”. Sophisticated equipment (maybe for molecular studies) is certainly shared collaboratively. Our members will also emphasize that it is “solution-sharing” which is the most valuable aspect of this project. It is extraordinarily rare these days to find a two day meeting devoted entirely to the regional discussion of applied and theoretical biological control. Our members consider this annual meeting the most important of the year.

Does the proposal include statements related to milestones; that is, time-linked accomplishments that must be complete before subsequent activities can begin or can be completed? Yes. Statements were made under the appropriate section as to time-linked accomplishments. Because this project covers over 168 different pest species, all projects are at different levels of completion. We describe how biological control programs must work in the US. They do have clear activities that must occur before the next step can proceed. Besides our many networked collaborations, our annual meeting, which takes place over 2 days, does actually provide a platform for very comprehensive discussion of cutting edge techniques and protocols for successfully controlling pests with biological control.

Does the proposal describe how results of the project are to be made available in an accessible manner to the intended users of the information (e.g., refereed publications, workshops, producer field days, etc.)? Yes. We clearly enumerate how we publish – both peer-reviewed research and extension papers. Websites, webinars, etc. were not requested to be itemized in the renewal proposal, but are numerous.

Other than the annual meeting, it is difficult to discern how the research findings are tied together in a collaborative manner. It would be desirable to publish all of the research findings every 5 years. In 1995, this project (then W-84) did receive funding to do just that. It had 83 chapters over 300 pages. Each chapter covered a different pest species and therefore was able to detail all of the timelines and milestones associated with each collaborative project from 1964-1989. Introductory chapters covered theoretical topics that were common to all objectives. The group will request appropriate funding from the Western Experiment Station to complete that objective and cover the past 30 years, similar to the above mentioned document. In addition, during our first annual meeting of the renewed project we will do an exercise to map out the various thematic collaborative networks within the project and include those results in an Appendix for the next Annual Report.

Collaborative projects listed by Objectives

Import and Establish Effective Natural Enemies (Classical Biological Control)  
  
Objective 1a. Survey indigenous natural enemies.   
W4185 participants working on this objective include those at these locations: CA (UCR, UCB, CDFA, USDA-ARS), CO, FL, Guam, HI, OR-DOA, MT, NM, WY. Of the 168 pest species the entire W4185 list as research targets, many have host ranges that encompass numerous western states or they threaten to move across the region.   
A short list of high profile pests this group works on includes: bagrada bug, brown marmorated stink bug, spotted wing drosophila, spotted lanternfly, Asian citrus psyllid, Russian knapweed, tamarisk, Arundo, hoary cress, leafy spurge, and starthistle.   
Example project: CO and MT researchers did collaborative surveys at 30 sites (15 in Montana; 15 in Colorado) of *L. draba* (hoary cress) for insect herbivores (both native and previously established introduced species) in preparation for evaluating the effects of releasing the recently approved mite biocontrol agent *Aceria drabae.* Consignments were also made to USDA-APHIS PPQ & CPHST, BLM, New Mexico State University, University of Wyoming, Washington State University, Wyoming Weed & Pest, Department of Agriculture in California, Oregon and Nevada, and the Nez Perce Biocontrol Center, and the biocontrol program at Whitehall High School, MT.

Objective 1b. Conduct foreign exploration and ecological studies in native range of pest.   
Several institutions in the western US conduct foreign exploration and importation of natural enemies for both new and established arthropod and weed pests. Species sent to quarantine facilities must survive the trip and reproduce. Subsequent cultures will then be used for non-target host testing and evaluation for potential release.

W4185 participants working on this objective include those at these locations: CA (UCR, UCB, CDFA, USDA-ARS), CO, HI, ID, OR-DOA, MT, NM, NV, WA, WY. In addition, a W4185 member that is critical to these objectives is CABI in Europe. CABI collaborates with many of these members to assist in foreign exploration and ecological and host testing before the biocontrol agent is transferred to a US quarantine facility.   
Example project: In collaboration with the CDFA and USDA Biological Control Laboratory in France, importation continued of *Psyllaphaegus* spp. attacking olive psyllid. This group also imported *Psyttalia ponerophaga* and *P. lounsburyi* attacking olive fruit fly.

Objective 1c. Determine systematics and biogeography of pests and natural enemies.   
  
W4185 participants working on this objective include those at these locations: CA (UCR, UCB), FL, OR, OR-DOA, MT, NY; as well as the USDA-ARS Beltsville, and the USDA EBCL in France.   
  
Example projects: Research (between UCR and cooperators in HI) continues on parasites of the imported fire ant (*Solenopsis*) in South America and of the Little Red Fire Ant (*Wasmannia*) in the Caribbean and Central America. Both standard Sanger-sequencing approaches, as well as novel anchored enrichment approaches to look at relationships and species identification across the entire genus are being used. In a larger phylogenetic analysis of the subfamily Oraseminae, results support an ancestral association with the genus *Pheidole*, followed by an ancient shift to the New World and diversification onto a wider variety of ant hosts, including *Solenopsis*, *Wasmannia* and other myrmicine ant hosts. Systematics research continues on leafminer parasitoids of the Citrus leafminer and the Citrus Peelminer. Studies are focused on a revision of the *Zagrammosoma* on a worldwide basis. Spearheaded by UCR, this very large systematics project involves numerous members: The NSF grant to revise the classification of the entire Chalcidoidea continues. This is a huge undertaking that involves molecular, morphological and bioinformatic approaches to resolve relationships of the superfamily, and to disseminate information on the group through electronic resources and a new book that outlines the classification and biology of the group. To date we have obtained nexgen sequencing data for over 600 taxa that cover the breadth of the entire superfamily. The following projects between our US and International W-4185 cooperating members all feature species that have been the subject of molecular and genetic work this year; a population comparison of a stem-feeding shoot fly (*Cryptonevra nigritarsis*) infesting *Arundo donax* in the south of France; genetic fingerprinting of a common garden experiment conducted in Greece to test the host plant specificity of the prospective biological control agent *Larinus filiformis* for *Centaurea solstitialis*; preliminary genetic comparisons between populations of the allium leaf miner (*Phytomyza gymnostoma*) in France and in the USA; genetic monitoring in choice and no-choice testing to ascertain the specificity of *Psyttalia ponerophaga*, a potential biocontrol agent of the olive fruit fly; phylogenetic analysis, species delineation and taxonomic revision of egg parasitoids of *Bagrada hilaris*; a study that resolved the taxonomic status of *Aprostocetus celtidis* and *A. suevius,* two *Pyrrhalta viburni* parasitoids; a genetic fingerprinting of *Trissolcus japonicus* on *Halyomorpha halys* from USA and Europe; and a genetic and morphological comparison of parasitoid assemblages of *Pyrrhalta viburni* and the closely related beetle *Xanthogaleruca luteola*

Objective 1d. Determine environmental safety of exotic candidates prior to release.   
  
W4185 participants working on this objective include those at these locations: CA (UCR, UCB), FL, OR, HI, MN; as well as USDA EBCL in France and CABI (Switzerland).

Example projects: In collaboration with researchers at USDA-ARS (CA), Oregon State University and colleagues in China and South Korea, researchers imported 8 parasitoid species that attack the spotted wing drosophila (*Drosophila suzukii*). These parasitoids included at least three larval parasitoids *Asobara* spp. , *Leptopilina japonica* and *Ganaspis brasiliensis*, and two pupal parasitoids, *Pachycrepoideus* *vindimiae*, *Trichopria drosophilae*. This material is currently being studied in quarantine. A cooperative project focusing on effects of intraspecific hybridization on host specificity of a weed biocontrol agent involves members from MI, CABI, MT, and CO. A global review of direct non-target attack research was published by CABI and ID W4185 researchers. This collaboration resulted in a number of comprehensive, theoretical studies about non-target impacts.   
  
Objective 1e. Release, establish and redistribute natural enemies.   
  
W4185 participants working on this objective include those at these locations: CA (UCR, UCB), CO, Guam, HI, ID, MI, MT, NM, TX.   
  
Example projects: in 2018, approximately 235,600 *Aulacidea acroptilonica* (a gall wasp) were redistributed to field sites from MT and among cooperators in CA, CO, ID, MT, NV, UT, WA and WY. Coconut Rhinoceros Beetles (CRB) invading Guam, Hawaii, Papua New Guinea, and Solomon Islands are genetically different from other populations of this pest, are resistant to *Oryctes nudivirus*, and behave differently. For these reasons, they are referred to as the "the Guam Biotype" CRB-G.  Ongoing testing of 30 *O. nudivirus* strains collected from the Philippines in 2017 has revealed a single strain that shows virulence to CRB-G. This strain was purified in New Zealand, and was subsequently sent to Guam where it was released during the Fall of 2017 using infected CRB as vectors. Results of this release have revealed no virulence of any of the cultured strains of *O. nudivurus* to CRB on Guam.

Objective 1f. Evaluate natural enemy efficacy and study ecological/physiological basis for interactions.   
  
W4185 participants working on this objective include those at these locations: CA (UCR, UCB, UCD, USDA-ARS), CABI, CO, FL, Guam, HI, KS, MN, MT, NM, NY, OR, UT.   
  
Example projects: Photoperiodic responses were reevaluated for diapause induction in three populations (Manhattan KS, Ithaca NY, Manitoba, Canada) of *Chrysopa oculata*, a predator of aphids and other soft-bodied pests. Hypotheses were that (1) mean temperatures and / or the variation in annual temperatures have increased at both localities as a result of changes in climate, and (2) *C. oculata* populations at all localities have made corresponding changes in their diapause-inducing photoperiodic responses. Flight and fecundity have been studied as a new means of measuring diapause induction of individuals of the species *Diorhabda carinulata,* a biological control agent of Tamarisk. Over 1000 beetles have had phenotypic measurements taken, and they are being sent to collaborators (CO) for genotyping. UT and CABI have been working on determining desirable exotic ladybirds for biological control of herbivorous insects.

Conserve Natural Enemies to Increase Biological Control of Target Pests  
  
Objective 2a. Characterize and identify pest and natural enemy communities and their interactions.   
  
W4185 participants working on this objective include those at these locations: CA (UCR, UCB, UCD, USDA-ARS), CABI, CO, Guam, HI, ID, MT, NM, OR, TX  
Example projects: The geographic origins of invasive populations of the mealybug *Planococcus ficus,* are being collaboratively determined by researchers at UCB, CABI, and OR. MT and CO collaborators are studying the effects of landscape composition on wheat stem sawfly and its braconid parasitoids. Researches at MN and CO are collaborating on determining characteristics of *Oporopsamma* *wertheimsteini* and *Sphenoptera* *foveola*, as two potential biological control agents of *Chondrilla* *juncea*. A large joint project between W4185 members in HI, CA, and USDA-ARS (EBCL) is looking at the early-acting competitive superiority in opiine fruit fly parasitoids. Guam, UCR, and CDFA (CA) are coordinating the movement of the parasitoid *Tamarixia radiata* from the CDFA insectary at UC-Riverside for release against Asian citrus psyllid, *Diaphorini citri*, on Guam.

Objective 2b. Identify and assess factors potentially disruptive to biological control.   
  
W4185 participants working on this objective include those at these locations: AZ, CA (UCR, UCB, USDA-ARS), Guam, HI, NM, OR, WY  
  
Example projects: Field studies suggest that a new Bt cotton targeting plant bugs and thrips has minimal non-target impacts based on natural enemy community sampling and life tables to assess impacts on biological control of whiteflies (AZ and CA).

Objective 2c. Implement and evaluate habitat modification, horticultural practices, and pest suppression tactics to conserve natural enemy activity.   
  
W4185 participants working on this objective include those at these locations: CA (UCR, UCB, UCD, USDA-ARS), CABI, NM, VT

Augment Natural Enemies to Increase Biological Control Efficacy  
Objective 3a. Assess biological characteristics of natural enemies.   
  
W4185 participants working on this objective include those at these locations: AZ, CA (UCR, UCB, UCD, USDA-ARS), CABI, CO, HI, MI, MT, NM  
  
Example projects: An on-going collaboration between researchers at UCR and AZ continues to elaborate the relationship between symbionts and parasitic hymenoptera. One area shows that transcriptome sequencing reveals novel candidate genes for *Cardinium hertigii*-caused cytoplasmic incompatibility and host cell interaction. Eriophyid mites are especially important in weed biocontrol. Collaborators in MT, CABI, and CA (USDA-ARS) work on defining their use and characteristics. MT and ID workers are jointly investigating *Oporopsamma* *wertheimsteini* and *Sphenoptera* *foveola*, two potential biological control agents of *Chondrilla* *juncea*.  
  
  
Objective 3b. Develop procedures for rearing, storing, quality control and release of natural enemies, and conduct experimental releases to assess feasibility.   
  
W4185 participants working on this objective include those at these locations: CA (UCR, UCB,), HI, NM, TX, USDA-ARS (EBCL).   
  
  
Objective 3c. Implement augmentation programs and evaluate efficacy of natural enemies.   
  
W4185 participants working on this objective include those at these locations: CA, FL, TX, VT  
  
Example projects: In collaboration with researchers at USDA, a project has released two pupal parasitoids, *Pachycrepoideus* *vindimiae* and *Trichopria drosophilae* near blue berry and strawberry fields to ‘inoculate’ these resident parasitoids before and after the harvest cycle. (USDA and UCB). A publication, *Guidelines for Purchasing and Using Commercial Natural Enemies and Biopesticides in North America*,

Evaluate Environmental and Economic Impacts and Raise Public Awareness of Biological Control  
  
Objective 4b. Develop and implement outreach activities for biological control programs.   
  
W4185 participants working on this objective include those at these locations: CA (UCR, UCB), Guam, HI, TX

Example projects: As part of an NSF project modules were developed (UCR as lead) 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. More outreach materials is being developed 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. Ideas for outreach are being vetted through a broad group of local teachers, and extension researchers at UC Riverside and Texas A&M University. Publishing a biological control textbook can be considered outreach. A major new textbook was produced by W4185 members from UCB and MN, *Biological Control: Ecology and Applications.* A publication, *Guidelines for Purchasing and Using Commercial Natural Enemies and Biopesticides in North America*, was produced by W4185 members from CA (ANBP) and FL to provide a comprehensive and up-to-date resource for finding commercially-produced biological control agents.

Select Publications from Collaborative Projects

2016-2021

Abram, P.K., K. Hoelmer, A. Acebes-Doria, H. Andrews, E.H. Beers, M.S. Hoddle, *et al*. 2017. Indigenous arthropod natural enemies of the invasive brown marmorated stink bug in North America and Europe. J. Pest Sci. 90: 1009-1020.

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