ABSTRACTS for
93rd Annual Meeting

Pacific Branch
Entomological Society of America

Bahia Resort Hotel
San Diego, California
March 29-April 1, 2009

Compiled according to presentation number in the program,
with paper presentations (0-117) followed by poster presentations (1-38).
No changes to spelling or grammar from the original abstracts were made.

PAPER PRESENTATIONS

0S. INTRODUCTION: ENTOMOLOGY AND EVOLUTIONARY THEORY: CELEBRATING 150 YEARS OF "ON THE ORIGIN OF SPECIES"

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Charles Darwin first published "On the Origin of Species" in 1859, introducing what is arguably the single most important organizational concept in the biological sciences. For 150 years, his theory of evolution by natural selection has been largely corroborated, with much evidence deriving from entomological circles. In celebration of the sesquicentennial of Darwin's groundbreaking work, young entomologists will be presenting elements of their research, emphasizing how their work contributes to the refinement of evolutionary theory.

1S. THE EVOLUTION OF FLIGHTLESSNESS IN CAVE AND ALPINE HAWAIIAN MOTHS

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Although the ability to fly confers benefits to most insects, some taxa have become secondarily flightless. Insect flightlessness may be more likely to evolve in specific environments than in others, including caves and alpine areas, but these predictions have never been tested in a way that controls for phylogeny: If flightlessness evolves only once in a group, followed by dispersal to similar habitats, then correlations between habitat type and flightlessness are spurious. This presentation focuses on two genera of Hawaiian moths, both of which were presumed to include multiple flightless taxa: *Schrankia*, with both cave- and surface-dwelling species, and *Thyrocopa*, with species occurring in alpine and below-alpine areas. This work has sought to determine whether flightless species or populations within each genus are sister to one another or not.

For *Schrankia*, only one species, *S. howarthi*, has invaded caves on two islands, Maui and Hawaii. Cave-adapted adults are not consistently flightless but instead are polymorphic for flight ability. Although the new species appears well suited to underground living, some individuals were found living above ground as well. These individuals, which are capable of flight, suggest that this normally cave-limited species is able to colonize other, geographically separated caves via above-ground dispersal. In this group, it is currently difficult to determine whether caves are correlated with flightlessness, though currently, selection may be favoring the reduction of flight ability.

In *Thyrocopa*, two independent alpine invasions and losses of flight have occurred. One flightless species lives on the summit of Haleakala on Maui, while the other lives near the summit of Mauna Kea on Hawaii Island. These two flightless, jumping "grasshopper moths" are more closely related to other low-elevation *Thyrocopa* species from their respective islands than they are to each other. Cold temperatures, high winds, and/or a lack of predation may be responsible ecological factors for the loss of flight in these alpine-living species. Loss of flight ability has evolved in a short period of geologic time.

2S. "ON THE INHABITANTS OF OCEANIC ISLANDS": FOUNDER EVENTS INFLUENCE DIVERSIFICATION IN A HOST-SPECIALIZED LINEAGE

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Understanding how lineages diversify is central to evolutionary biology, and founder events are proposed to sometimes be involved in the generation of diversity within lineages whose histories appear to involve rapid radiations. Darwin (1859) noted about the Galapagos that "…the inhabitants of each separate island, though mostly distinct, are related in an incomparably closer degree to each other than to the inhabitants of any other part of the world", setting the stage for over a century of research on oceanic archipelagos aimed at explaining what combination of factors drives this observed pattern. Phytophagous insects are excellent model systems for investigating the processes of diversification because of their extremely high diversity and specialized lifestyles. The genus *Nesosydne* (Delphacidae: Hemiptera), is incredibly speciose on the Hawaiian Islands. Our study uses evidence from multiple molecular data sets to describe the biodiversity patterns at multiple evolutionary scales. We report evidence that founder events have played a role in generating the striking patterns of genetic diversification in a Big Island species from this group.

3S. CAN QUANTITATIVE POLLINATION WEBS PROVIDE INSIGHT TO CO-EVOLUTION WITHIN A DEGRADED HAWAIIAN ECOSYSTEM?

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Recent concerns about the worldwide decline of pollinators and the possible ecosystem-wide consequences incurred highlight the importance of understanding how pollinator communities interact and change as natural ecosystems degrade and are invaded by alien species. Pollination webs provide information on how these systems function and change, and may provide insight into how species co-evolve and how species loss may alter these

co-evolved relationships. Most of Hawaii's native ecosystems have undergone massive conversion and loss, with many members of the flora and fauna becoming rare or extinct. Hawaiian tropical dry forests in particular, are one of the most endangered ecosystems in the world. Currently, less than 10% of these forests remain, and what is left is highly degraded and found in small remnant patches. Non-native plants and insects dominate the landscape in and around these remnant patches. To understand how community interactions may be altered by a degradation of an ecosystem, I constructed a quantitative pollination web to answer the question of whether natives interact more closely with natives, and non-natives with non-natives. When the web is separated into native pollinators and non-native pollinators, native pollinators only visit native plants in addition to only three non-native plants. In comparison, non-native pollinators show no preference between native and non-native plants. The native bee fauna, a monophyletic group within the genus *Hylaeus*, shows remarkable adherence to native plants, even though these plants species are from a variety of families with extremely different flower morphologies. Because of this fidelity, I investigated whether the native bees were better pollinators than the more common non-native honeybees. To test whether native bees were more efficient pollinators of native plants, a randomized block design was employed. The results suggest that, while the plants require a visitor for increased seed set, the identity of the pollinator is not important. In terms of co-evolution, the native bees appear to be using cues other than flower morphology, color or shape to choose what plant species to forage on. The native plant species whose seed set were investigated appear to have evolved away from self fertilization, but have not evolved toward a specialized pollinator system.

4S. TRANSPOSABLE ELEMENTS: A STRONGE FORCE IN GENOME EVOLUTION

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With the publication of several important insect genomes: *Drosophila melanogaster, Anopheles gambiae, Apis mellifera, Aedes egypti* and *Tribolium castaneum,* the genomic era is offering entomologists new tools to study evolution. Comparative and functional genomics provide the ability to revolutionize the field of Entomology and shed light on the phylogentic relationships as well as the evolutionary history of an insect species. These genome projects have opened the door to look more closely and expansively at important genetic components such as transposable elements. Transposable elements (TEs) are mobile pieces of DNA with the ability to insert themselves within a host genome thus establishing their continual propagation within a population. For example, TEs represent approximately 47% of the *Aedes aegypti* genome and 8% of the *D. melanogaster* genome highlighting both the prevalence and difference of TE loads in different insect species. Recently, studies have implicated the RNAi silencing pathways in the suppression of the mobility of these elements enabling an organism to retard TEs ability to spread within the genome. The ubiquitous distribution of these elements is an

excellent example of Darwin's "Survival of the fittest" representing an interesting host/parasite relationship that deserves further investigation. Moreover, through the comparative analysis of TE location, number, regulation and domestication much can be learned about an organism's evolutionary history.

5S. DIVERSIFICATION AND BIOGEOGRAPHY OF THE CRYOPHILOUS INSECT FAMILY GRYLLOBLATTIDAE

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Historical climate change has caused the diversification and extinction of species, as well as rapid shifts in population size and geographic distribution. Over the last three million years, animals and plants in temperate latitudes have responded to climatic cycles of prolonged cooling (glaciations) followed by rapid, but short periods of climate warming. Glacial episodes enabled cold-adapted species to disperse and diversify beyond the limits of their current geographic ranges. The Grylloblattidae are a small, enigmatic group of insects found exclusively in western North America and northeastern Asia. All living species are cryophilic, preferring cool and often freezing temperatures, and have a highly fragmented distribution. Species are largely restricted to high elevation mountains, caves, and deep canyons where cold temperatures persist during summer months. Using genetic data, I reconstruct the phylogenetic relationships and biogeographic history of 5 grylloblattid species in California. During a long history in California, grylloblattids have expanded from the mountains into low elevation habitats, where they have persisted by colonizing caves and canyons. My results reveal cryptic genetic diversity, suggesting several isolated populations may be new species. Finally, I compare the biogeographic patterns in California to distantly related grylloblattids in northeastern Asia, to look for similarities in the diversification of cave-dwelling and alpine ecologies.

6S. CO-SPECIATION OF INSECTS WITH THEIR BACTERIAL ENDOSYMBIONTS

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Many insects possess bacterial endosymbionts that are obligate for insect survival and reproduction, and are termed as primary symbionts. Co-speciation of obligate primary symbionts with their insect host, stemming from a single infection, is widely found among several insect orders. Parallel phylogenies between insect hosts and their primary endosymbionts are found within aphids, psyllids, whiteflies, tsetse flies, carpenter ants, cockroaches, and primitive termites. Interactions between vertically transmitted PS and

insects are thought to be ancient, and have lead to drastic changes in PS genomes. Primary symbionts are very important for their insect hosts and may be responsible for facilitating the expansion of some insect taxa into unique nutrient poor niches.

7S. INSECTICIDE RESISTANCE: EVOLUTION IN THE VISIBLE SPECTRUM

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Insects are a dynamic group of organisms with a long evolutionary history. Through a long evolutionary process, they have developed the ability, dynamic genetic norms of reactions, to adapt to the changing environmental conditions including those of anthropocentric origin, such as insecticide applications. The development of insecticide resistance is one of the most amazing cases of evolutionary adaptation to environmental change, especially when we consider that it has occurred relatively quickly in terms of evolutionary time. It is a major global challenge that threatens human welfare through its impact on crop protection and disease transmission. Further understanding of insecticide resistance will provide fundamental insights into evolution, genetics, physiology, and ecology, and is needed to design techniques for resistance management. We tested field-collected populations of obliquebanded leafroller (OBLR), and selected a laboratory population for resistance against some novel insecticides. We observed significant variation in the susceptibility of field-collected populations to those insecticides. The LC_{50} values of OBLR for chlorantraniliprole and spinetoram were significantly increased after few generations of selection, and the trait was heritable. In another study, we also observed reversion of a field-collected population from being resistant to completely susceptible to azinphosmethyl, after few generations in the laboratory without insecticide applications. Based on our studies with OBLR, we conclude that the risk of resistance evolution against recently registered insecticides with novel modes of action exists, and this is the best time to develop and implement resistance management strategies to delay the evolution of resistance and control the major pests of tree fruits on sustainable basis.

8S. EXPLORING THE EVOLUTION OF THE HAWAIIAN *NYSIUS* SEED BUG LINEAGE: PHYTOPHAGY TO CARNIVORY IN 500,000 YEARS?

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The genus *Nysius* has a global distribution of 106 species, many of which are designated as agricultural pests. The 26 Hawaiian *Nysius* demonstrate more morphological diversity than is found in the rest of the *Nysius* species of the world. Most compelling about this

Hawaiian genus is the presence of two wingless predator/scavenger species on Hawaii Island. The phylogeny of this genus sheds light not only on the colonization and radiation of the genus throughout the entire Hawaiian archipelago, but it also creates a framework to study this extreme and rapidly altered feeding strategy from herbivory to carnivory. The DNA (mtDNA, COI, COII and nDNA EF1α) of fourteen of the 26 species have been sequenced so far. We have also been able to obtain *Nysius* from New Zealand, French Polynesia, and the USA mainland for use as outgroups. The phylogeny of the genus was reconstructed using maximum parsimony and maximum likelihood analyses in PAUP* (Swofford, 2005). The two predaceous species' closest relatives are *N. lichenicola* and *N. blackburni*, which have no known predatory or omnivorous habits. There is some evidence for the progression rule in the Hawaiian *Nysius*, with *N. fullawayi* from Midway being basal to the Hawaiian *Nysius*. These results are preliminary, but do indicate a monophyletic Hawaiian clade supporting a single introduction, not the 5 to 12 separate introductions suggested by Usinger in 1942.

9S. RAPID SPECIATION REFUTED: MOLECULAR DATA DO NOT SUPPORT RECENT DIVERSIFICATION OF *OMIODES* (LEPIDOPTERA: CRAMBIDAE) ONTO A NON-NATIVE HOSTPLANT

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Hawaiian leafroller moths (*Omiodes*: Crambidae) have been often cited as products of rapid speciation due to anthropogenic effects. Five Hawaiian *Omiodes* species have been reared only from the leaves of banana, a plant brought to Hawaii by humans less than 1500 years ago. Because these five species are clearly part of a monophyletic endemic radiation, yet have no known native host plant, it has been presumed that all five species radiated from a common ancestor after banana was introduced. Until recently, studying this system using genetic tools was impossible, since the banana-feeding species were presumed to be extinct, and amplification of DNA from museum specimens was unsuccessful. Recently, however, we collected two specimens of these banana-feeding *Omiodes* in light traps, enabling us to assess the "rapid speciation" hypothesis by examining rates of divergence of mitochondrial and nuclear genes. Although we were not able to calibrate a molecular clock for *Omiodes*, levels of divergence in mitochondrial sequences suggest that the banana-feeding complex diverged much earlier than previously thought, sometime on the order of 2 million years ago. This suggests that banana is a secondary host for these species, and that they originally diversified on native hostplants which are now unknown. Not only does this provide insight into the processes of hostplant-driven speciation, but it suggests that we have been looking in the wrong places to relocate these presumably extinct species, and that they may persist on rare or inconspicuous native hostplants.

10. CONTROLLING MOTH PESTS BY MATING DISRUPTION: MULTIPLE PATHS TO EFFICACY

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The first demonstration of protection of a crop by broadcast application of synthetic pheromone was reported by Harry Shorey and colleagues in 1977. Pink bollworm (*Pectinophora gossypiella*) pheromone was dispensed on cotton strings draped over cotton fields of the Coachella Valley and season-end damage levels by this pest matched those of conventional practice fields. Since then, this method has been tried with many other moth pests, usually with success (e.g., codling moth (*Laspeyresia pomonella*), oriental fruit moth (*Grapholita molesta*), and gypsy moth (*Lymantria dispar*). At present, mating disruption is used in management of a number of important moth pests, with a yearly application to over 750,000 ha of crops and forests.

Does each species require a unique formulation and mix of behaviorally active chemicals, or are there are common threads in methodology that forecast successful control? The methods used for mating disruption vary widely—there are different types of formulation and therefore patterns of spatial application, ranging from innumerable point sources achieved with sprayable formulations, to point sources deployed at rates of only 100s per ha, to atomizers ("puffers) set out at only several per ha. Only point-source formulations are attractive to males. As well, the disruptant itself is usually but not always a copy of the complete natural pheromone, and, if it is not, the formulation, even if it is of the point-source type, may not evoke attraction. Such differences in formulation type and disruptant compounds dictate differing mechanisms of disrupting mate finding. These are thought to be sensory impairment (CNS habituation/receptor adaptation), competition between artificial pheromone sources and unmated females, and a camouflage of pheromone plumes from calling females. The ecological requirements for success also vary with species—some species require low pre-treatment population levels and little influx of mating females from non-treated areas.

Although we now have many successful examples of direct control of major moth pests by mating disruption, the principles learned suggest that no single approach for formulation or the actual disruptant used will suffice for every species, although for some species, several formulation approaches have proved efficacious. Lastly, some species, because of their migratory behavior, may prove intractable to this approach.

11. HAPPY 50th BIRTHDAY PHEROMONES

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The identification of bombykol as the sex pheromone from the silkworm moth, *Bombyx mori*, five decades ago marked the beginning of the molecular era in insect olfaction and paved the way for multidisciplinary approaches to tackle the intricacies of insect chemical communication. Electrophysiological methods, developed almost simultaneously with the identification of the first sex pheromone, and behavioral studies, particularly with the advent of wind tunnels, highlighted the inordinate specificity of chemical signals and the sensitivity of the insect olfactory system. The "gold rush" to understand these remarkable features of the insect olfactory system at the molecular level was initiated with the discovery of pheromone-binding proteins, which by now have been dissected at the biochemical, biophysical, and structural levels. As studies progressed and the literature became dichotomous regarding specificity of PBPs the then elusive pheromone receptors were placed on a pedestal as the molecular panacea. Just before the turn of the century receptor molecules were identified. As we probe these receptors with multiple approaches, questions arise about their specificity. We now raise the glasses to celebrate Butenandt's discovery, but they appear only half full.

12. SIMULATION OF MATING DISRUPTION AND MASS TRAPPING USING THE EFFECTIVE ATTRACTION RADIUS

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The effective attraction radius (EAR) is a key parameter in a recent simulation model of mating disruption and mass trapping with competitive attraction and camouflage (Byers 2007). The active-space model that is complex and poorly defined can be conveniently replaced with the EAR in models of mass trapping/mating disruption as shown by comparative simulations (Byers 2008). Other simulations were used to explore variation of key model parameters such as lure and female EAR dimensions and densities on efficacies of mating disruption and mass trapping of insects, especially moths. Male moth movement was simulated as a correlated random walk during random encounters with EAR of lures of variable radius and density. Calling female moths were in competition with lures in attracting males that oriented in the EAR for various periods. Females could be camouflaged by lure EAR but were allowed to move positions at various rates. When male orienting time was constant regardless of EAR, the models indicated no difference in mating disruption efficacy between either a higher density of dispensers with smaller EAR, or a lower density of dispensers with a compensating larger EAR. However, when the orienting time was increased in proportion to dispenser EAR, then fewer dispensers

with larger EAR were more effective in reducing female mating than were more numerous ones with smaller EAR. When costs of pheromone are substantial, however, more numerous dispensers of smaller EAR would be more economical since dose-response curves in previous studies indicate release rate must increase exponentially to achieve a linear increase in EAR. Mass trapping reduced mating more than mating disruption given equivalent conditions (Byers 2007). Use of the EAR in two-dimensional encounter rate models requires a conversion as shown in simulations of flying insects in three-dimensions that were flying in a normal distribution with height (Byers 2009). The models are useful in understanding and developing successful mating disruption or mass trapping programs.

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13. ADOPTION OF PHEROMONE TECHNOLOGY IN APPLE AND ITS IMPACT ON IPM PROGRAMS

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The successful use of pheromones as a control for tree fruit pests occurred first with the Oriental fruit moth, *Cydia molesta* (Busck). This was fortuitous in many respects because it technology worked so well and this encouraged the development of other pheromones for pest control in perennial cropping systems. The registration of pheromones as a control for codling moth, *Cydia pomonella* L., occurred before there was sufficient information to supports its use by growers. Early research pointed to benefits and risks associated with this new technology in apple IPM but adoption by pome fruit growers as a viable codling moth control was slow. The codling moth areawide management project (CAMP), which was funded by USDA-ARS funds from 1995-1999, provided the necessary evidence that pheromones were a viable control for the codling moth and adoption rates increased dramatically. Lessons learned in CAMP were adopted in many other places around the world and the use of pheromone technology for codling moth control continued to increase. In Washington State mating disruption of codling moth is the foundation for a pheromone-based IPM system in apple production. In 2008 we estimate that 80% of the bearing apple acres in Washington were

treated with pheromone to control codling moth. Use of pheromones allows growers to reduce supplemental insecticides for key pests and has helped stabilize control of secondary pests through enhanced biological control. As pome fruit production enters into a period where organophosphate (OP) insecticides are being eliminated or further restricted and reduced risk and OP replacement insecticides are adopted the relative value of pheromone technology has increased. One reasons is that pheromone technology has become a less expensive tool relative to the cost of new insecticides. Because pheromones reduce input of insecticides their use represents an important tool in a sound resistance management strategy. And finally because pheromones are high specific they are an idea IPM tactic for conserving biological control agents in orchards.

14. SEMIOCHEMICALS FOR DETECTION AND CONTROL OF CERAMBYCID BEETLES

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The cerambycid beetles comprise a large insect family, with well over 30,000 described species. Many of these species are large and colorful, and are well known to naturalists and insect collectors. However, surprisingly little is known about the biology of many species, despite the fact that a number are important pests in forestry, urban forests, and perennial crops. Furthermore, they are increasingly important as invasive exotic pests because the long-lived larval stages are readily moved around the world by human commerce in wood products, dunnage, and wooden packing cases. Despite their economic importance, only a few pheromones or other specific semiochemical attractants have been identified for cerambycids. However, that situation is changing rapidly, with efforts underway in North and South America, Europe, and Asia to identify and develop practical applications for cerambycid pheromones. Here, we will briefly review the current status of cerambycid pheromone studies, and biological, economic, and practical issues related to the development and use of cerambycid pheromones for detection and management of native and exotic cerambycid species.

15. BARK BEETLE HOST SELECTION BEHAVIOR: THE THEORY AND PRACTICE BEHIND PROTECTING FOREST TREES WITH REPELLENT SEMIOCHEMICALS

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For the last decade and a half, scientists and pest managers interested in applying the tools of chemical ecology to the management of coniferous bark beetles have been guided by a new awareness and understanding of the complexity of host selection behavior (Fig. 1). Anderson (1948) and Wood (1963, 1972, 1982) pioneered our comprehension of how a bark beetle finds its host, generally in the context of pheromone-guided aggregation behavior. Borden (1997) and Zhang and Schlyter (2004) refined the concepts to include the behavioral signals involved in nonhost avoidance. In brief, when selecting a coniferous host to colonize, bark beetles encounter a series of alternatives. Under the hypothesis of directed flight and landing guided by long-range olfaction, a searching beetle must determine if a tree is i) the correct host tree species; ii) not occupied at a high colonization density or for a long duration by other bark beetle species or woodborers; iii) not occupied at a high colonization density or for a long duration by bark beetles of the same species; and iv) susceptible to attack (Fig. 1; Borden, 1997; Graves et al., 2008).

If these criteria are met, a beetle may accept and successfully colonize its host. If not, the beetle may reject the host and continue searching. Theoretically, each of these decision nodes (i-iv) is marked by an olfactory behavioral chemical that is either attractive or interruptive to the flying or walking insect. Because of the reliance by the beetle on this chemical communication-based decision process, there is potential to exploit this process to reduce the impact of bark beetles on forest trees (Borden, 1997).

Examples of semiochemicals from these nodes that have been used experimentally or operationally to interrupt bark beetle flight behavior include green leaf volatiles such as (*Z*)-3-hexen-1-ol, (*E*)-2-hexen-1-ol, and (*E*)-2-hexenal (node i), 3-methyl-2-cyclohexen-1-one (MCH) and verbenone (nodes ii and iii), the spiroacetal *trans*-conophthorin (nodes i and ii), and the phenylpropanoid 4-allylanisole, which is also known as methyl chavicol (node iv). A case study of the development of a ground-based tree protection method for standing spruce in Alaska illustrates how the combination of even two of the semiochemicals from these various nodes can work synergistically and efficaciously to repel the northern spruce engraver, *Ips perturbatus*, from attractant-baited funnel traps and trees.

We contend that in the future, scientists and managers concerned with bark beetles should be guided by the idea that just like multicomponent pheromone blends,

there is a benefit to isolating and identifying multicomponent interruptant blends, in which the components are derived from various trophic levels and ecological players in the process of host colonization. This notion is similar to the 1960's paradigm shift from the "silver bullet" concept of single component sex and aggregation pheromones (Silverstein, 1981) to multicomponent blends because it suggests that the most efficacious and ecologically relevant interruptants or disruptants will also consist of multiple components. However, in this case the components are drawn from various levels of ecological organization rather than from the target species alone. The future challenge of this approach will be to identify all or most of the components from the ecological sources and then select the most efficacious subset of components to arrive at an economically feasible product. Among other benefits, the application of multicomponent interruptants may forestall the development of behavioral resistance in populations of bark beetles exposed to single-component treatments.

With this new emphasis on holistic/integrative thinking and new sources of stimuli, specific future enhancements to the practice of applying repellant semiochemicals for the management of bark beetles may come from 1) amplifying the resistance of conifers to bark beetles and fungi through the application of the naturally occurring plant hormones, such as jasmonic acid, or its analog, methyl jasmonate (MJ) [3-oxo-2-(2-pentenyl)-cyclopentaneacetic acid, methyl ester]; 2) exploitation of semiochemicals that guide short range olfaction or gustation; 3) application of non-pathogenic fungi to occupy host niche space and/or provide a source of repellent

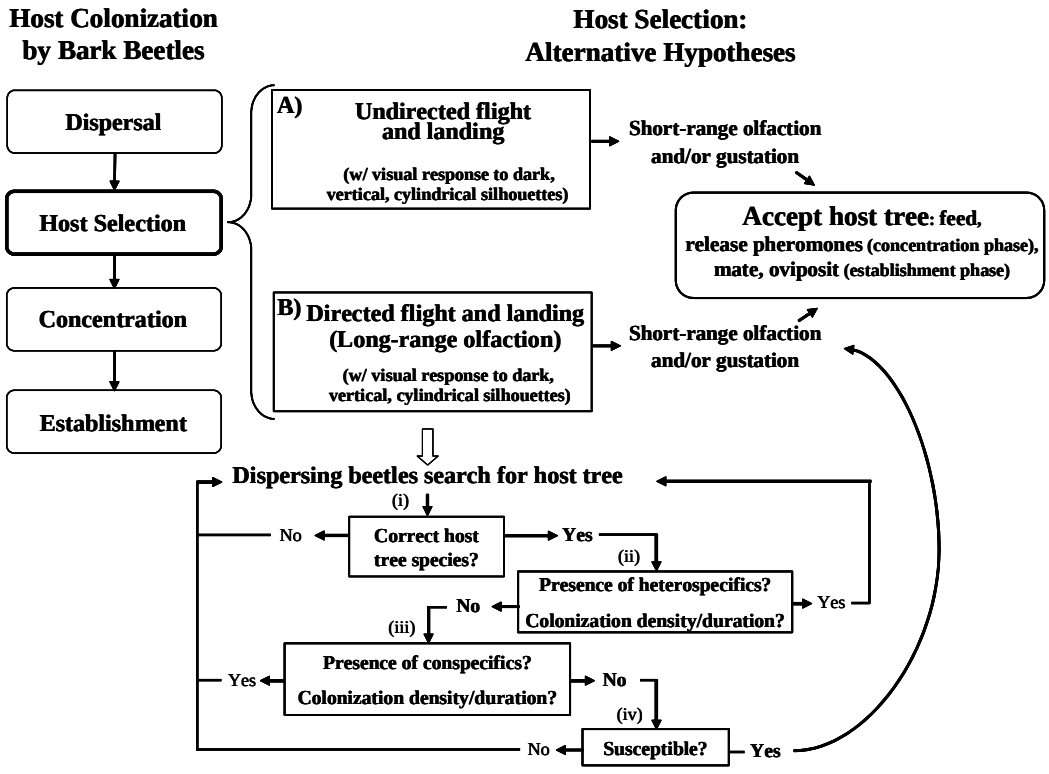

Fig. 1) Host colonization by bark beetles can subdivided into four phases (dispersal, host selection, concentration, and establishment) according to Wood (1982). Two major hypotheses to describe host selection are based on (A) undirected flight or (B) directed flight in response to long-range olfactory signals (Wood, 1982; Borden, 1997). Prior to (long-range) or after landing, a bark beetle may undergo a series of binary decisions to evaluate the host tree species, followed by the level of occupancy, suitability, and susceptibility of a host (Borden, 1997). Figure adapted from Graves (2008).

semiochemicals such as 1-octen-3-ol; or 4) the potential use of vertically transmitted microorganisms to disrupt the production or response of beetles to their semiochemicals.

In the Alaska case study, a novel coupling of the phenomena of interruptive insect behavioral chemistry (verbenone and *trans*-conophthorin) with induced host resistance (by MJ) was tested as a low environmental impact management strategy for *I. perturbatus*. The combination of the beetle-produced compound (verbenone) and the non-host volatile (*trans* -conophthorin) reduced the colonization density and, ultimately, the mortality of Lutz spruce, *P. ×lutzii*, associated with *I. perturbatus*. However, the applications of MJ did not have any influence on the experimental outcome, suggesting that variables such as dosage and timing of the application of the phytohormone need to be optimized in future research projects.

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16. SUSTAINABLE, AREA-WIDE BARK BEETLE MANAGEMENT USING ANTIAGGREGATION SEMIOCHEMICALS

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Bark beetles in the genus *Dendroctonus* have recently caused unprecedented damage to western North American forests. A series of large-scale studies have demonstrated the potential of pheromone-releasing laminated flakes to manage *Dendroctonus* spp. bark beetles in these coniferous forests. The flakes, which will soon be available in a biodegradable formulation, can be applied using fixed-wing aircraft or helicopters. Alternatively, they can be broadcast from the ground using fertilizer-spreaders or can be sprayed directly onto tree trunks using a special hand-carried applicator. Area-wide tests were conducted using 150 grams of active ingredient (AI)/acre, and sprays onto individual trees were done using 15 grams AI/tree. Aerial application tests of verbenone-releasing flakes targeting *D. ponderosae* in whitebark pine and lodgepole pine stands showed reductions in attack rate of 60-70%, depending on stand conditions and beetle population levels. Rate of attack by *D. pseudotsugae* in Douglas-fir stands was reduced by 90% with aerial application of methylcyclohexenone-releasing flakes. When sprayed onto individual lodgepole pine trunks from ground level, verbenone-releasing flakes provided almost complete protection to trees baited with aggregation pheromone. Nontarget insect responses were recorded in most of these studies, and there were no significant disruptions of the natural enemy complexes.

17. PROMISE UNFULFILLED: COMMERCIAL USE OF PLANT CHEMISTRY FOR PEST MANAGEMENT

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The study of insect-plant chemical interactions enjoyed explosive growth beginning in the 1970s, and continues unabated today. Thousands of plant extracts or isolated

constituents thereof have demonstrated behavioral or physiological activities against one or more species of arthropods, most of which are considered pests of agriculture or forestry, or are of veterinary or human health importance. Yet, in spite of this relative wealth of scientific information, there is a dearth of pest management products whose active ingredients are sourced from higher plants. Only a handful of botanical insecticides are in commercial use today, and just two types (those based on neem [azadirachtin] or on essential oils) have been commercialized in the past 20 years. Plant-derived insect antifeedants were long hailed as a potentially non-toxic tool for crop protection, but a number of operational shortcomings have prevented their practical use in agriculture. The concept of combining the use of insect attractants with repellents/deterrents in a "push-pull" strategy to lure pests away from high-value crops is intriguing, but has seen few viable demonstrations. The emerging area of pest-induced host plant volatiles – some of which attract natural enemies of pests – is gaining momentum. One potential use of induced hostplant volatiles is as the basis of an "early warning system" for detecting pest infestations in controlled environments (e.g. greenhouse cropping systems) at levels invisible to the naked eye of human scouts. Such a monitoring system could be built around a network of inexpensive but selective chemosensors, integrated with GPS through artificial intelligence systems.

18. PLANTS CRYING FOR HELP: HOW HERBIVORE-INDUCED PLANT VOLATILES CAN IMPROVE CONSERVATION BIOLOGICAL CONTROL

D. James, V. Hebert, L. Wright, J. Lepage, and D. Brooks

Deployment of synthetic methyl salicylate (MeSA), a herbivore-induced plant volatile (HIPV), in controlled release dispensers (CRD) in hops and grapes in the Pacific Northwest (PNW) of the United States has been demonstrated to increase populations of beneficial insects, improve conservation biological control (CBC) and suppress pests. Identifying and understanding the chemical-ecological and eco-physiological mechanisms mediating beneficial insect attraction to HIPV, is a current focus of this work. Determining whether beneficial insects are recruited by direct attraction or whether plants are stimulated by synthetic HIPV to produce their own beneficial insect-attracting volatiles, is a key question. Preliminary results from laboratory experiments indicate that hop plants exposed to CRD of MeSA emit a different profile of volatiles compared to unexposed plants. Some of these volatiles from MeSA-exposed plants are known attractants of beneficial insects and/or repellents for pests. Turning on or telling plants to produce their own natural enemy attractants is an appealing idea and strategy, and may be responsible for much of the success seen hitherto in improving natural enemy populations and CBC in PNW grapes and hops. Field experiments in Washington and New South Wales, Australia using agricultural spray oil formulations with MeSA or other synthetic HIPV, applied to hop, grape, sweet corn and broccoli plants, have demonstrated recruitment of some natural enemy species. This might be a more cost-effective and practical way of delivering synthetic HIPV to plants.

19. *IN SITU* VOLATILES FROM A SINGLE CULTIVAR OF *PRUNUS DULCIS*, AND THEIR RELATIONSHIP TO NAVEL ORANGEWORM

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Nonpareil almonds, *Prunus dulcis*, account for the largest percentage of almond varieties grown in the Central valley of California. Several studies have investigated the various non-volatile and volatile components of various plant parts; however, the volatile organic compound (VOC) emission of almonds from a single cultivar has not been studied over the course of an entire growing season. This aspect is particularly relevant to research concerning the navel orangeworm (NOW), a major insect pest of almonds and other tree nuts. Despite several flights of NOW, the identification of particular VOCs, or their potential correlation to NOW flights, has not been addressed. The VOC emission of Nonpareil almonds was collected *in situ* over the course of a growing season by solid-phase microextraction (SPME). The VOCs (*Z*)-hex-3-enyl acetate, (*Z*)-hex-3-enyl butyrate, undecan-2-ol, β-bourbonene, caryophyllene, and α-humulene exhibited distinct emission during the 1st and 2nd flights of NOW. Several VOCs exhibited positive electroantennographic (EAG) signals from male and female NOW moth bioassays.

20SP. SUBLETHAL EFFECTS OF PESTICIDE RESIDUES WITHIN HONEY BEE COMB AS A CONTRIBUTING FACTOR TO CCD?

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European honey bees, *Apis mellifera* (L), are important pollinators and are at risk of non-target pesticide exposures. Colonies can be exposed to pesticides by in-hive treatments used to control bee pests, such as mites. During foraging, honey bees are also exposed to various pesticides that can further contaminate the colony. Acute poisoning kills the entire colony or cause losses of workers and obvious damage to brood. However, sub-lethal effects can result in learning and memory impairment, reduced longevity, early supersedure of queen or other effects not readily evident. This study examines sub-lethal effects of pesticide residues within brood combs on the overall health and development of worker bees and assesses its potential as a contributing factor of colony collapse disorder (CCD). My research compares growth and development of worker bees reared on combs from untreated colonies and combs from colonies treated with miticides. Mortality was recorded at each developmental stage from egg to adult to assess and compare vitality of bees within each treatment. Adult bees are observed for differences in age polytheism. These comparisons provide useful information for beekeepers and scientists interested in

the effects of pesticides on honey bees and the potential link between pesticide loads and CCD.

21SP. DETECTION AND INTEGRATED PEST MANAGEMENT FOR BLACK GRASS BUGS

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The native Black Grass Bugs (BGB - *Labops spp*. and *Irbisia spp.* – Hemiptera: Miridae) has been reaching infestation levels in naturalized invasive crested wheatgrass (*Agropyron cristatum*) monocrops and other early season forage grasses in the western U.S. The infestations are worsened by long term drought conditions adding additional stress to range grasses. In order to control BGB populations a suite of cultural control measures must be implemented. The available control measures are, heavy grazing, mowing/haying, disk and harrowing, controlled burning, native grass re-seeding and pesticide applications. The Black Grass bug has been shown to lay its eggs in the upper portion of desiccated, year-old grass stems, making post-egg laying habitat removal a promising method of controlling outbreaks. Detection of BGB infestations can be accomplished with multispectral high resolution satellite or aerial imagery. Using multivariate regression analysis damage is statistically apparent in both the red and infra-red bands. This detection method combined with the various control measures offer land managers a suite of options to control BGB outbreaks.

22SP. POPULATION DYNAMICS AND SAMPLING OF CUCUMBER BEETLES IN CALIFORNIA MELON AGROECOSYSTEMS

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Cucumber beetles (Chrysomelidae) are serious economic pests of melons grown in northern and central California. Western spotted cucumber beetles (WSpCB), *Diabrotica undecimpunctata undecimpunctata* Mannerheim, and Western striped cucumber beetles (WStrCB), *Acalymma trivittatum* Mannerheim, both cause cosmetic scarring to the rind of melon fruits in the adult and larval forms. Throughout the 2008 growing season, monitoring of both species was done at three organic melon fields in Yolo County using sticky traps. This data led to the conclusion that the WStrCB appears to have 3 generations developing in melon fields each season while the WSpCB appears to have only 2. The number of beetles per plant were also estimated visually early in the season. Significant linear relationships were found between the number of beetles in the visual searches and the number of beetles on the traps for both species combined and WStrCB alone but not for WSpCB alone. Sweep net collections and soil sampling indicate that

WSpCB uses alfalfa fields as an overwintering site and host for the larvae and adults during the melon growing season. Alfalfa may be an important source of WSpCB infestations in melons and currently a greenhouse study is in progress to further investigate this.

23SP. MOSQUITO CAPTURE RATES IN TRAPS WITH/WITHOUT WILD BIRDS, AND HOST PREFERENCE OF CAPTURED MOSQUITO SPECIES

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The surveillance for and control of mosquito populations and the pathogens they carry is essential for the prevention of mosquito-transmitted diseases like west Nile virus. With the large number of individual mosquitoes that must be collected for a robust pathogen surveillance program, it is important that Mosquito Abatement and Vector Control Districts have mosquito trap methods designed for efficient collection of important vector mosquitoes. One common practice to increase trap catch by placing mosquito traps near wild bird hosts has never been validated.
The purpose of this study was to determine if the capture rate of a mosquito species in CO2-baited suction traps is altered by the proximity of wild birds. In addition, blood fed mosquitoes collected with wild birds were tested by multi-plex PCR to determine their host feeding preference. Host blood was identified by amplification of the cytochrome b sequence of the four bird species used in this study.

24SP. USING A NATIVE FISH AS AN ALTERNATIVE BIOCONTROL METHOD TO THE MOSQUITOFISH, *GAMBUSIA AFFINIS*

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Arroyo chub, *Gila orcutti*, a fish endemic to Southern California, has been proposed as a replacement biological control agent for the invasive mosquitofish, *Gambusia affinis*, in sensitive watersheds throughout southern California. Survival and efficacy of the chub at controlling larval mosquitoes, specifically *Culex tarsalis*, the Western Encephalitis mosquito, will be evaluated at the Prado Wetlands in Orange County, California. It has

been shown that mosquito-eating fish are not strictly larvivorous in their diets. They also have the potential to impact non-target organisms and cause trophic cascading in systems where they are introduced. Based on this tendency, we will study the impact of predation by the chub on the aquatic community that co-occurs with mosquito larvae in man-made wetlands, specifically the macroinvertebrate and planktonic communities. The chub has been designated as a "Species of Special Concern" by Cal. Dept. of Fish and Game and the long-term goal is to provide Vector Control Districts with a native alternative to *Gambusia*, while helping to enhance the chub population and return the fish to its native range.

25SP. RESISTANCE RISK ASSESSMENT FOR NOVEL REDUCED-RISK INSECTICIDES IN OBLIQUEBANDED LEAFROLLER (LEPIDOPTERA: TORTRICIDAE)

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Obliquebanded leafroller (OBLR), *Choristoneura rosaceana* (Harris), is one of the most destructive pests of tree fruits in Washington. The use of broad-spectrum insecticides against OBLR for decades has led to the development of insecticide resistance in this pest. In this situation, the recently developed chemicals with novel modes of action including rynaxypyr and spinetoram, show promise for controlling OBLR, but resistance remains a threat. The risk assessment for resistance to a particular insecticide before its occurrence in the field could be valuable in developing strategies to manage susceptibility. Studies were initiated to test field-collected populations, and select a laboratory population for resistance against rynaxypyr and spinetoram to determine the risk of resistance evolution using quantitative genetic techniques. We treated 2000 neonates from laboratory population at LC_{70}-LC_{90} for 96 hours using diet-incorporation bioassay at each generation. After six generations of selection, 7- and 4-fold increases in LC_{50} values were observed for rynaxypyr and spinetoram, respectively. The realized heritability values were estimated as 0.11 for rynaxypyr and 0.08 for spinetoram. The response quotient (*Q*) was used to compare the rate of resistance development in OBLR against these insecticides. The *Q* values were 0.113 and 0.071 for rynaxypyr and spinetoram, respectively. These results indicate that the risk of resistance development in OBLR would be higher against rynaxypyr than that against spinetoram.

26SP. CONTROL OF CITRUS THRIPS, *SCIRTOTHRIPS CITRI,* ON BLUEBERRIES WITH *BEAUVERIA BASSIANA* IN THE SAN JOAQUIN VALLEY OF CALIFORNIA

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Citrus thrips, *Scirtothrips citri* (Moulton), is a plant-feeding pest most widely recognized for damage caused to citrus and mango fruits. Recently, it has broadened its known host range to become a significant pest of blueberries grown in California's San Joaquin Valley. Knowledge of this insect's life cycle coupled with determining that most pupae pupate in the soil in blueberry fields has suggested the possibility of using *Beauveria bassiana* (Balsamo) to aid in field control of thrips in the upper layers of soil beneath the plant canopy as an alternative to traditional pesticides. Two formulations of *B. bassiana* (commercially available Mycotrol O versus *B. bassiana* colonized millet seed) were tested in the field under two different irrigation schemes and data were collected via emergence cages covered with sticky cards. The results of this trial will be discussed.

27SP. RESPONSES OF MALE *HYALOPTERUS PRUNI* AND *BRACHYCAUDUS HELICHRYSI* TO DIFFERENT BLEND RATIOS OF APHID SEX PHEROMONE

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Mealy plum aphids, *Hyalopterus pruni* (Geoffroy), and leaf-curl plum aphids, *Brachycaudus helichrysi* (Kaltenbach), are two major pests of California's dried plum (i.e., 'prune') crop. In the major prune producing regions of California, both species exhibit holocyclic heteroecious life cycles involving alternating generations. The sexual stage of the life cycle occurs in prune crops in the fall, during which time males respond to sex pheromones produced by oviparous females. The sex pheromones produced by oviparous mealy plum aphids (MPA) and leaf-curl plum aphids (LCPA) are species-specific blends of two pheromone components, (*4aS, 7S, 7aR*)-nepetalactone and (*1R, 4aS, 7S, 7aR*)-nepetalactol. The objective of the current study was to determine the attraction of male MPA and LCPA to water traps baited with different blend ratios of the nepetalactone and nepetalactol components. The experiment was conducted in four prune orchards in California, two located in Yolo County and two in Sutter County, during the fall of 2008. Water traps, positioned in the tree canopy, were baited with one of seven sex pheromone blends or a no-pheromone control and the numbers of male MPA and LCPA in each trap were quantified weekly. The following neptalactone:nepetalactol ratios were included in the experiment: 1:0, 0:1, 1:1, 2.6:1, 3.4:1, 5:1, 7:1, and 0:0 (no-pheromone control). The results of this study will be presented and the potential for utilizing aphid sex pheromones to enhance monitoring and control of MPA and LCPA will be discussed.

28SP. INTRASPECIFIC VARIATION IN PENETRANCE OF *WOLBACHIA*-INDUCED THELYTOKY IN THE PARASITOID WASP, *TRICHOGRAMMA KAYKAI*

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Trichogramma are tiny egg parasitoids widely used in the biological control of a multitude of lepidopteran pests. Several species of *Trichogramma* are infected with *Wolbachia,* a maternally transmitted, bacterial endosymbiont renowned for its ability to manipulate the reproductive processes of its hosts. In most infected *Trichogramma, Wolbachia* manipulates host reproduction by inducing thelytoky—the parthenogenetic production of female offspring. This *Wolbachia*-induced reproductive manipulation eliminates the need for males in thelytokous populations of *Trichogramma.* Since females are the effective sex in parasitoid biological control programs, researchers are interested in the potential advantages *Wolbachia*-infected, thelytokous *Trichogramma* may have over their sexual counterparts.

Wolbachia's ability to consistently manipulate host reproduction is an important factor to consider when assessing the potential benefits of using thelytokous *Trichogramma* for biological control. In this study, we compare the penetrance of *Wolbachia*-induced thelytoky in three genetically distinct isofemale lines of *Wolbachia*-infected *Trichogramma kaykai*. Differences in sex ratios, particularly male and intersex production, are presented. Likely impacts of these results on the potential use of *Wolbachia*-infected, thelytokous *Trichogramma* as successful biological control agents are discussed.

29SP. UTILIZATION OF A NATIVE MYCOPHAGOUS COCCINELLID AS AN INDICATION AND DECISION SUPPORT DEVICE FOR MANAGEMENT OF GRAPE POWDERY MILDEW IN A COMMERCIAL VINEYARD

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Powdery mildew (PM) is the most important pathogen of winegrapes in California. Management includes use of the UC Davis PM risk assessment index (RAI) model to predict pathogen development so that fungicides can be used more efficiently. The initiation mechanism for this model is based on weather data supplemented by manual scouting, resulting in some early-season inaccuracies. The use of a native mycophagous beetle, *Psyllobora vigintimaculata* (Coleoptera: Coccinellidae), as an indicator for PM may offer solutions to this problem. Monitoring over three consecutive years in a commercial vineyard, utilizing manual leaf inspection and yellow sticky card sampling for beetle presence and density as well as PM presence and severity, has revealed several

important trends. Adult beetles were adept at locating isolated and low-density PM infections. Also, the local density of adult beetles in the vineyard was positively correlated with the severity of PM infecting the grapevines in the immediate vicinity. In 2007 and 2008 the RAI model overestimated disease risk in April and May, but the incidence of locally trapped adult beetles in these months closely followed the actual observed PM severity on leaves. There are possibilities for using local beetle density to predict local PM severity and for using beetle presence as a component of the RAI model.

30SP. KILLING TWO BIRDS WITH ONE STONE: NON-TARGET EFFECT OF DIMILIN ON HORN FLIES

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Grasshoppers compete directly with cattle for available rangeland forage. They consume roughly 25% of prairie vegetation in 17 western U.S. states at a cost of $900 million/yr. Horn flies (*Haematobia irritans* L.) have been a major pest to cattle in the United States since the mid 1880s. Infestations cost the industry close to $1 billion/yr through control costs and production losses. Dimilin 2L, an insect growth regulator (a.i. diflubenzuron), inhibits immature insects from properly molting and has been used successfully in controlling nymphal grasshopper outbreaks. We are examining the secondary effects of Dimilin applied for grasshopper control on horn flies. We hypothesize that, after feeding on Dimilin-treated vegetation, the insecticide would pass through the cows' digestive tract and affect the horn fly larvae which develop in the dung. We present data from summer 2008. Our preliminary observations indicate that Dimilin decreases the numbers of horn flies emerging from dung deposited in the areas treated with the insecticide compared to untreated rangeland.

31SP. EFFECTS OF TEMPERATURE ON GROWTH AND DEVELOPMENT OF EPEORUS ALBERTAE (MCDUNNOUGH) (EPHEMEROPTERA: HEPTAGENIIDAE) NYMPHS

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Factors affecting macroinvertebrate community assemblage in freshwater systems are becoming increasingly more important for understanding this vital resource. Macroinvertebrates serve as indicators of stream habitat quality, and knowledge of habitat preferences and tolerance ranges for key taxa in different ecosystems is useful for understanding the ecological processes and functions. This study examined the effect of water temperature on the growth and development of *Epeorus albertae* (Ephemeroptera:

Heptageniidae) nymphs. As anticipated, insects held at higher temperatures exhibited increased growth rates. Additionally, it was demonstrated that higher temperatures affected the type of growth of the nymphs; growth ratios comparing head capsule width to total body length were significantly different in higher temperature treatments. This change in development has the potential to affect the fecundity and overall success of the emergent adult. Temperature in river systems can be affected by many different kinds if disturbance events, and the effects on the biota are worthy of examination, to improve our understanding of ecosystem processes and functions.

32. BIOLOGY AND MANAGEMENT OF THE ASIAN CITRUS PSYLLID – THE FLORIDA EXPERIENCE

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The Asian citrus psyllid, *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae), was first detected in Florida in 1998 and rapidly colonized the entire state making eradication unfeasible. Direct feeding damage caused by psyllids is limited to new flush and thus is of little concern for mature bearing citrus groves. However, the importance of this pest is due to its status as the vector of the bacterial pathogen *Candidatus* Liberibacter asiaticus, the causal agent of citrus greening disease, also known by its Chinese name as 'Huanglongbing' (HLB). Thus, following the discovery of the psyllid in Florida, citrus growers put forth no effort in managing psyllid populations since it was assumed that the bacterial pathogen vectored by *D. citri* was not present. Consequently, psyllid populations regularly reached high levels in citrus groves throughout the state.

Following the discovery of the HLB pathogen in Florida in 2005, intensive efforts began towards managing *D. citri* populations with the goal of keeping psyllid populations as low as possible to reduce the rate of pathogen spread. Early attempts at controlling developing psyllid populations on new flush using selective insecticides proved ineffective. Management programs then shifted to the use of broad-spectrum insecticides to target adult psyllids prior to the presence of new flush, providing much more consistent and reliable control of *D. citri* populations. Despite repeated applications of broad-spectrum insecticides in Florida citrus groves, sustained control of *D. citri* is complicated by the dispersal behavior of this insect. Through mark and release studies, *D. citri* was found to move daily between managed and abandoned groves highlighting the importance of managing psyllids on an area-wide basis.

The success of area-wide psyllid management is dependent on treating all citrus groves in a defined area in as short of time as possible to minimize the rate of re-infestation of previously treated areas. The effectiveness of both aerial and low-volume ground applications of insecticides to rapidly achieve control of psyllids populations has been

demonstrated and are now being incorporated into area-wide psyllid control programs by Florida growers.

In a study to determine the percentage of *D. citri* carrying the HLB pathogen on a month by month basis, two distinct periods of the year, fall and spring, were identified as times when pathogen spread was more likely to occur under typical Florida conditions. This study is being continued in 2009 to determine if the trends remain consistent from year to year. Such information could be used to reduce insecticide applications to times of the year when pathogen transmission is most likely to occur.

33. BASIC HLB BIOLOGY AND FLORIDA DETECTION METHODS

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Since the discovery of Huanglongbing (syn= citrus greening, HLB) in Florida in 2005, commercial producers in the state have been trying to mange the disease using a strategy of detection and roguing, vector control, and the use of disease-free planting and replanting material. Fundamental to the management process is the early detection of the disease and the subsequent removal of infected trees to manage the inoculum load in the groves. Since some of the symptoms of HLB are similar to other grove maladies, Florida growers have relied on laboratory testing to train and "calibrate" their scouting crews. Based on the three years of laboratory testing and field observations, it is apparent that there is some periodicity to the spectrum of symptoms of HLB in Florida and to the titer of the bacterium in the trees. Similarly, differences have been noted in varieties and spatially within different blocks and plantings. Practical field observations, laboratory data and testing methods will be presented to help guide the California industry as it begins the process of surveying for HLB after the discovery of the Asian Citrus Psyllid in the southern part of the state. Information will also be presented on the scouting and control measures and the cost of implementing these control strategies in a large corporate citrus operation.

34. ESTABLISHMENT AND SPREAD OF *DIAPHORINA CITRI* HUANGLONGBING IN FLORIDA

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Diaphorina citri Kuwayama probably became established in Florida in early 1998 within 6 months to 1 year of its initial establishment. It was distributed throughout the state primarily through retail trade in *Murraya paniculata* sold as ornamental plants. Early surveys indicated that the initial psyllid population was free of huanglongbing. Although huanglongbing was discovered in 2005, the extent of its distribution indicated that it had been in Florida for several years. The initial delimiting survey found that the highest incidence of infection was in the SE urban areas of the state. By January 2009, confirmed infected plants had been found in 32 counties, and infected *D. citri* had been found in three more counties. Thus, huanglongbing spread approximately 540 km (320 mi) in 10 years after the initial discovery of psyllids in the state. Classic epidemiological data indicate that most psyllid vectors do not fly far. An incursion rate of 20 km (12 miles) per year is proposed in the literature for Brazil. We postulate that longer psyllid flights in the absence of host material and distribution of infected plants and infected insect vectors in retail trade may account for the much more rapid rate of spread in Florida.

35. ASIAN CITRUS PSYLLID STATUS IN SOUTHERN CALIFORNIA

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Asian citrus psyllid (ACP), *Diaphorina citri*, is the major vector of the huanglongbing disease of citrus. ACP was first discovered in San Diego County, California in August 2008. ACP is currently found in portions of San Diego and Imperial Counties. This talk will present the latest information on the extent of the infestation in Southern California and the steps being taken by the California Department of Food and Agriculture and its cooperators to eradicate, control, and limit the infestation of this pest. Current detection methods employ the use of visual surveys, yellow panel sticky traps, and insect vacuuming devices. Management practices currently employ the use of imidicloprid soil drenches and cyfluthrin foliar sprays. Results of various detection strategies will be presented as well as results of the eradication methods being employed.

36. REGULATORY IMPACT OF ASIAN CITRUS PYSLLID (ACP) IN SOUTHERN CALIFORNIA

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The purpose of regulatory activities is to contain the movement of a pest. This job is quite daunting when dealing with Asian citrus pysllid due the insect's small size and its ability to be carried by the wind. Currently the ACP quarantine encompasses 5,131 square miles and covers portions of San Diego and Imperial Counties. All establishments are regulated if they handle, move or sell any host plants of ACP. These host plants include many members of the family *Rutaceae.* Establishments that are regulated are nurseries that must treat all nursery stock and can only sell plants inside the quarantine area. Interstate shipment is allowed only when plants are shipped to areas already infested with ACP or to states without citrus production. Citrus growers must commercially clean their fruit prior to leaving the quarantine area to remove all leaves and debris or send the fruit to a packing facility inside the quarantine area. Other establishments such as cut flower producers, packing houses and landscapers that deal with green waste also must prevent the movement of host material. Hardships to regulated establishments are occurring that deal mostly with the cost and time delay of selling plants and fruits due to pesticide treatments or cleaning of fruit to meet regulations.

37. SURVEY STRATEGIES FOR ASIAN CITRUS PSYLLID IN SOUTHERN CALIFORNIA

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The Asian citrus psyllid (ACP) *Diaphorina citri* Kuwayama (Homoptera: Psyllidae) was detected in San Diego County in August 2008; since then multiple finds along the U.S.-Mexican border has resulted in a 5,000 sq. mi. quarantine that includes the southern region of San Diego and the entirety of Imperial Counties of California.

Detection of ACP is time consuming, expensive, and requires specialized training. Simple and efficient sampling procedures are needed to evaluate the presence and relative abundance of ACP in host plants. The primary survey methods used for detection are yellow sticky traps, visual, stem tapping, and P-Vac machines. Ideally, sampling should concentrate on new growth because nymphs feed on the new growth and adults are present on the host plant. The timing and abundance of the infestation in California necessitates surveying year-round during non-flush periods. Low populations of psyllids decrease the likelihood of detecting all stages of psyllids. The suppression of ACP by

CDFA eradication efforts using pesticides effectively decreases the relative abundance of ACP. Populations in California have not reached sufficient levels to allow for reliable detection of immature stages. Consequently, survey methods in California have targeted adult psyllids. The P-Vac machine allows inexperienced inspectors to rapidly sample host trees in one trip. Optimal results are achieved when multiple survey methods are used in concert with specialized training.

38. ASIAN CITRUS PSYLLID MANAGEMENT IN TEXAS

Mamoudou Sétamou

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The Asian citrus psyllid (ACP), vector of citrus greening disease (= Huanglongbing [HLB]), was first detected in Texas in 2001. Because of the psyllid high reproductive potential and the availability of suitable hosts throughout south Texas, ACP has invaded many counties in Texas and its populations are on the rise in recent years. With the discovery of HLB in Florida in 2005, the pest status of ACP increased dramatically in the U.S., including Texas where area-wide surveys initiated in 2006 have not thus far detected the presence of HLB. However, to curb the threat of HLB in Texas, aggressive area-wide control strategies of the psyllid vector are the more likely and readily available options to growers and nurserymen. Based on ACP population fluctuations in relation to flush cycles in Texas, IPM strategies compatible with each type of orchard (organic or conventional) were developed and implemented. Efficacy of aerial and ground treatment applications for the control of ACP was also compared. ACP populations were monitored by yellow sticky cards every two weeks, and also by visual observation of flush shoots. Four spray applications, each prior to a major flush cycle, provided excellent control of ACP populations year round. In addition, aerial spray applications of fenpropathrin (e.g. Danitol) and imidacloprid (e.g. Provado) by fixed-winged aircraft were as effective as ground applications by airblast sprayers. Aerial application was cheaper and faster allowing large areas to be covered within a short period of time, making it a viable option for psyllid control in large commercial groves. Biopesticides such as neem and kaolin provided some help, but no long term control was achieved. Because neem acts as a knock down of incipient populations, and kaolin as a deterrent preventing subsequent infestation, it is recommended to combine these pesticides for effective psyllid control in organic orchards.

39. EXPLOITING THE DYNAMICS OF NEONICOTINOID INSECTICIDE UPTAKE INTO CITRUS FOR THE EFFECTIVE MANAGEMENT OF ACP

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Imidacloprid is a neonicotinoid insecticide used for the management of ACP on citrus. This insecticide acts systemically within the trees following application to the soil. The insecticide is absorbed from the soil by the root system for distribution throughout the tree in the vascular system. The ACP is a phloem feeder, so this mode of application would seem to be ideal to exploit the insect's feeding behavior. However, the uptake of imidacloprid can be affected by many factors, and effective lethal concentrations of insecticide may not be delivered to the feeding sites of the insect. One of the most important factors affecting uptake is soil type. Components within the soil (such as clay content) can bind the insecticide, retarding its availability for root absorption. Also, once the insecticide has been absorbed by the roots, its movement within the xylem system is affected by its chemical properties. In mature citrus, imidacloprid may take several weeks to reach peak concentrations, a time delay that may not be acceptable to growers because of the potential for insect colonization and disease transmission. However, once the imidacloprid becomes established within the tree at effective concentrations, it has the potential to persist for long periods, thereby reducing the need for additional pesticide treatments.

Some of the problems associated with the use of imidacloprid in heavy soils may be overcome by using alternative neonicotinoids. Thiamethoxam and dinotefuran are generally more available for uptake from the soil due to greater water solubility. The movement of these insecticides is also less restricted within the vascular system and toxic concentrations could be attained at insect feeding sites much more quickly. However, while these insecticides may be distributed throughout the tree more rapidly, their persistence is not generally as good as the persistence of imidacloprid. A lack of persistence can compromise the level of protection of a tree, particularly during times when new flush is being produced.

Systemic neonicotinoids are already proving highly effective against the ACP on backyard citrus in California. If the insect becomes established on commercial citrus, it will be important to implement chemical control programs that exploit the properties of these insecticides to best effect.

40. DETECTION OF HUANGLONGBING BACTERIA IN PSYLLIDS (*DIAPHORINA CITRI*) AND ITS IMPORTANCE IN DISEASE MANAGEMENT

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Huanglongbing (HLB or citrus greening) is a serious disease of citrus which limits citrus production in Asia and Africa. Surveys conducted immediately following the discovery of HLB in Brazil (2004) and Florida (2005) revealed that the disease was too widespread in both places to attempt eradication. Our field experiments suggest that infected plants may have long incubation periods, sometimes over two years, and that psyllids can acquire the HLB associated bacteria (*Candidatus* Liberibacter spp.) from non-symptomatic infected trees. Analyses of psyllid samples collected from orchards, nurseries, garden centers, fruit trucks and other sources suggest that the disease moved rapidly throughout Florida through diverse means. Unregulated retail nurseries, garden centers and the ornamental plant industry appear to have played a major role in rapid spread of the disease throughout the state. HLB associated bacteria were detected in psyllids in several counties well before infected plants could be detected. Analysis of psyllids for HLB associated bacteria from orchards under different management practices showed that it can be a powerful tool for effective monitoring. However, only a small percentage of adult psyllids carrying HLB associated bacteria can be found even from severely infected groves. Incidence of HLB bacteria in psyllids appears to exhibit some seasonality. Hence continuous monitoring of large number of psyllids throughout the year is essential in surveys for early detection. With the arrival of psyllids in California, it is important to realize that while the newly HLB-infected plants may take several months to years before the associated bacteria can be detected, the same bacteria in psyllids can be detected within days after acquisition. Early detection of HLB is vital for survival of citrus industries and detection of HLB-associated bacteria in psyllids is the most powerful tool available at present. HLB management should include monitoring both psyllids and plants and prevention of the movement of psyllids through fruit and nursery materials by strict regulation.

41. INDUSTRY JOINS BATTLE AGAINST ASIAN CITRUS PSYLLID (ACP) AND HUANGLONGBING (HLB)

MaryLou Polek

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The Citrus Research Board (CRB) has delved into new territory. Once focused mainly on funding research projects that would improve and maintain the viability of the citrus

industry in California, the board has taken unprecedented action by establishing an Operations Department to protect their industry. Realizing the gravity of the detection of ACP in San Diego and Imperial Counties and the complexities of attaining eradication and containment, the industry joined efforts with the USDA, CDFA, and County Agricultural Commissioners to augment detection and eradication activities in southern California and to develop regional, long-term control strategies including Arizona, Texas, and Mexico. The Operations Department will consist of three areas; laboratory, field, and GPS/GIS. By the end of 2009, three high throughput diagnostic laboratories will be set up to analyze psyllids and plant material for the presence of HLB-associated bacteria. Field staff will work cooperatively with government agencies to deploy traps, collect samples, and train industry and the public sector on psyllid and disease symptom detection. Global positioning and geographical information systems will be implemented to track traps, trees, and samples. Resulting data will be used to develop management strategies for the entire southwest citrus production region.

42. CHEMICAL INDUSTRY RESPONSE TO PSYLLID CONTROL

Marc Fisher, Dow AgroSciences; Mike Ansolebehere, Valent USA Corporation; Ryan Bounds, Syngenta Crop Protection; Wayne Steele, DuPont Crop Protection; Sam Wells, Bayer CropScience

Huanglongbing disease (HLB) and its accompanying insect vector, the Asian citrus psyllid (ACP), have again brought to the forefront the need for cooperation between all stakeholders in the citrus industry stakeholders. One of the important stakeholders that is key to managing ACP is the chemical industry. Chemical manufacturers provide many of the important tools currently used by the citrus industry to manage ACP.

Chemical manufacturers, however, face difficult challenges in their efforts to provide effective management tools. These challenges include regulatory, environmental, economic, and scientific hurdles. Chemical manufacturers often find themselves straddling the competing interests of growers, regulators, environmental parties, citizens, and investors, while trying to remain economically viable. In addition, manufacturers must maintain consumer and regulatory confidence by ensuring products meet rigid scientific standards for product efficacy and safety.

This section of the symposium gives representatives from the chemical manufacturing industry an opportunity to address the issues they face. Representatives from BASF, Bayer CropScience, Dow AgroSciences, DuPont, Syngenta, and Valent will each discuss their specific companies in the form of five minute mini-presentations . Product efficacy data will be shared, regulatory hurdles will be discussed, and time will be opened at the end of the talks for questions from the audience.

43. MOLECULAR- AND GENOMIC-BASED STRATEGIES TO MITIGATE THE IMPACT OF CITRUS HUANGLONGBING DISEASE

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Huanglongbing (HLB) is a destructive disease that is an increasing threat to citrus production in many citrus-growing areas around the world, including California. The HLB pathosystem is complex. The etiology of HLB is not completely understood. However, several potential pathogens are associated with the disease. At least three "*Candidatus* Liberibacter" species (asiaticus, africanus, americanus) are most commonly associated with three different forms of HLB. Also, two phytoplasmas have recently been associated with the disease in Brazil and China. The potential etiological role(s) of other known (e.g. virus(es), and perhaps unknown, etiological agents in HLB is not clear. "*Ca.* Liberibacter" species are transmitted by the Asian citrus psyllid (ACP). Phytoplasmas are also psylllid-transmitted. No curative treatments are available and disease management is currently based primarily on exclusion through local, state and federal phytosanitary regulations and quarantines; early disease and insect vector detection and eradication; and chemical treatments to control insect vectors of HLB-associated pathogens. Current and emerging molecular biological and genomics technologies are likely to play a key role mitigating the impact of HLB. PCR-based protocols are being used to increase the effectiveness and reliability of early clinical detection and identification of HLB-associated "*Ca.* Liberibacter" species (as well as other known potential pathogens) *in planta* and *in insecta*. In addition, advances (e.g., microarray analyses of gene expression) are also being made in identifying early host response(s) to infection by HLB causal agent(s) before these are detectable in asymptomatic clinical samples. Detection of pre-symptomatic HLB-associated host responses may be an alternative approach to clinical pathogen detection for identifying infected plants. Novel, field-deployable platforms (e.g., lateral flow cytometry) are also being developed for rapid, sensitive, specific, reliable detection of HLB-associated "*Ca.* Liberibacter in plants and psyllids. Genomic characterization of the HLB-associated pathogen(s) (e.g., "*Ca*. Liberibacter" species, phytoplasmas), as well as the microbial biomes associated with HLB-affected citrus trees and psyllids, is likely to provide essential information about the diversity of potential HLB-associated agents for understanding the etiology and epidemiology of the disease. Determination of the genetic bases of host-pathogen-insect interactions should lead to the identification of potential targets to interfere with acquisition, transmission, infection, multiplication and *in planta* movement of HLB-associated "*Ca.* Liberibater" species (and other potential pathogens). Microarray analyses of HLB-affected plants elucidate how infection by "*Ca.* Liberibacter" alters citrus host gene expression leading to disease development. This information is expected to be useful in developing HLB disease management strategies. There is no known resistance to HLB in currently cultivated commercial citrus species, hybrids and varieties; however, there is some indication of HLB tolerance in some citrus rootstocks (e.g., Aurantiodeae). Candidate genes for improving citrus germplasm, including cultivars for

commercial cultivation, with enhanced resistance to HLB are being sought through comparative transcriptome analyses. Improved citrus germplasm with enhanced HLB resistance will also include transgenic technology. Systemic acquired resistance (SAR) is a mechanism of induced host defense that may confer long-lasting protection against a broad spectrum of biotic agents (e.g., pathogens, insects). Manipulation of SAR inducer-mediated defense signaling could be based on gene regulation and expression to stimulate broad sprectrum resistance to HLB. Transgenic citrus trees producing anti-microbial proteins (AMPs; e.g., D4E1), chimeric pathogen surface-binding plus AMP protein, enzymes (e.g., PGIP) that inhibit pathogen-critical proteins, toxins (e.g., defensive volatiles), micro-RNAs, and insect vector repellent volatile organic compounds (VOCs) interfere with infection and disease development. Transgenic rootstocks might be developed for delivering HLB-resistance factors (e.g., AMPs) or signals into the scions without the need for transgenic scions. Transgenic plants producing insect vector attractant VOCs might be used as sentinel plants around or near citrus groves. Metagenomics approaches are being used to identify pathogens (e.g., viruses) that may be potential biological control agents of the ACP. HLB will continue to be managed most effectively based on an integrated systems approach based on exclusion and removal of inoculum sources and insect vectors through phytosanitary regulations and cultural practices, early detection of HLB-associated potential pathogens and insect vectors, control of insect vectors, and host resistance or tolerance. However, in the future, these disease and insect vector management strategies will be increasingly enhanced by advances in integrating genomics, engineering, and HLB and insect vector biology.

44. THE IMPACT OF THE ASIAN CITRUS PSYLLID INVASION ON CITRUS IPM

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Asian citrus psyllid (ACP), *Diaphorina citri*, is a pest of new flush of citrus, causing twisting and death of leaves that can slow the growth of young citrus. Asian citrus psyllid arrived in dooryard citrus in southern California in 2008 and is threatening to spread to commercial citrus. This psyllid is an efficient vector of the bacterium that causes Huanglongbing disease of citrus that is causing devastating losses of Florida citrus. Currently the disease is not found in California, however, to protect commercial citrus from the disease, an aggressive ACP eradication program is in progress in urban areas and a quarantine has been set up around infested areas. There will be several phases of the invasion of ACP that will affect the citrus industry. Commercial citrus fruit can not be moved out of the quarantine area without being washed packed. As ACP and the quarantine boundaries spread and envelope significant citrus acreage, growers will respond with increasing numbers of insecticide treatments. Insecticides will be applied to reduce the risk of moving citrus fruit contaminated with ACP and to reduce the natural spread of the psyllid around the state. If Huanglongbing is found in California, then treatments will escalate in an effort to reduce the spread of the disease by reducing vector

densities. There are no effective organic insecticides available for ACP control and the majority of pesticides that are used in Florida are broad spectrum in nature; organophosphates, carbamates, pyrethroids and neonicotinoids. Currently, San Joaquin Valley citrus growers treat only 2-3 times per year for all citrus pests and other regions of California treat even less and have a very effective integrated pest management (IPM) program utilizing primarily soft pesticides and natural enemies. An additional 4-6 insecticide treatments per year are likely to be needed to manage ACP once it becomes established. This will have the direct effect of an increase of $360-540/acre in pesticide and application costs, but also escalate costs due to secondary outbreaks of other pests because of the disruption of IPM.

45. THE INTEGRATED CONTROL CONCEPT FROM THE VERN STERN PERSPECTIVE

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Professor Vernon Stern served on the University of California (UC), Riverside faculty from 1956 until retirement in 1991. He was a pioneer in the development of Integrated Pest Management. In 2006, he was honored as one of the top ten UC Riverside scientists who had the greatest impact on agriculture in 100 years of the UC citrus experiment station. His 1959 Hilgardia publication, "The integrated control concept" with Drs. Ray Smith, Robert van den Bosch and Ken Hagen is a citation classic. Stern's general study outlining integrated control concepts has formed the basis for much of the applied work in entomology that has been practiced since 1959. The man, his philosophy and impact on *Lygus* bug management in the California agricultural ecosystem will be presented.

46. THE CALIFORNIA PEAR IPM PROGRAM—A 50 YEAR HISTORY OF PESTICIDE USE AND TRANSITION TO BIOLOGICALLY INTENSIVE IPM

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During the 1960's, the pear industry in California was among the heaviest agricultural users of pesticides on a per acre basis. At least 14 active ingredient insecticides and miticides were being applied annually in multiple sprays. These included chlorinated hydrocarbons, organophosphates and carbamates. In spite of heavy pesticide inputs, pest control costs and pest damage were escalating due to pesticide resistance, pest resurgence and pesticide related inducement of secondary pest outbreaks. The pear industry was suffering classic symptoms of the "pesticide treadmill". By the late 1960's, key pear industry leaders were demanding relief. Simultaneously, new pest monitoring technologies were being researched and new commercial infrastructure for site-specific

implementation of these technologies was developing. With public and environmental activism on the rise in the wake of Rachel Carson's *Silent Spring*, the stage was set for implementation of an emerging new concept—*Integrated Pest Management*. This paper discusses the components of that change, highlighting how pear growers, university researchers, extension agents, private consultants, government regulators, farm chemical suppliers, environmentalists and the agricultural chemical industry collaborated (often unwittingly) towards successful transition into biologically intensive IPM. Today, arthropod management in pears is relatively low input and very successful. Pear growers now apply as little as 3-5 active ingredient insecticide/miticide products per season, most of which are organically certified. This practitioner will discuss some of the key lessons learned.

47. THE EVOLUTION AND CURRENT STATUS OF INTEGRATED PEST MANAGEMENT IN CALIFORNIA CITRUS

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Citrus pest management has had a long history of integrated pest management in California, with some 120 years of implementation. Commercial citrus production began in southern California in the 1840's soon after William Wolfskill established his commercial grove three blocks northeast of the current location of Los Angeles' City Hall. With completion of the transcontinental railroad in 1869, the citrus industry rapidly expanded shipping its fruit to the lucrative east coast markets. This lasted for several decades until the cottony cushion scale was inadvertently imported on ornamental acacia trees from Australia and transferred to citrus. This scale rapidly spread throughout southern California via the young trees used to establish new citrus plantings as the industry rapidly expanded after the 1870's. The effects of cottony cushion scale on citrus trees were devastating and threatened the young industry's viability. Fortunately, two of the scale's natural enemies, the Vedalia beetle and an agromyzid fly, *Cryptochaetum iceryae* (Will.), were discovered in Australia and subsequently imported and released in 1888. The result of this introduction was spectacular, as the two natural enemies rapidly suppressed the scale outbreak in Wolfskill's grove. This dramatic success led to the distribution of these natural enemies throughout southern California's citrus groves; thus saving the fledgling citrus industry. It also validated biological control as a viable pest management tactic.

This initial success led to an era of unbridled faith in biological control. But it was soon dampened when other exotic pests were introduced and became economic. Most of these pests were initially unknown to science, as were the identities of their natural enemies. This led to exploration for their natural enemies, many of which were unsuccessful. This spurred the development of spray oils and HCN fumigation as a means of controlling many of the exotic pests. Thus began the 120 year evolution of citrus pest management in California which initially began in southern California, and subsequently

spread to some of the citrus groves in the San Joaquin Valley. One of the tactics developed during this period was a method of producing insectary reared natural enemies for release into citrus groves. This program was initially developed by the Fillmore Citrus Protective District and P. DeBach. It included frequent inspection for citrus pests in its members' groves. This tactic, when combined with HCN fumigation and augmentative releases of black scale parasitoids, substantially reduced the cost of producing citrus over that typical of the region. This method was practiced until HCN resistance began to develop in the armored and soft scales. Augmentative biological control was subsequently developed and coupled with the timely establishment of a number of biological control agents for these pests. These tactics yielded high quality fruit at a cost substantially below that of a more traditional insecticide based program and it was practiced until the Fillmore Protective District was displaced by urbanization in 2003. Thus, all of the tactics of an IPM program were developed by elements of the southern California citrus industry in collaboration with the Division of Biological Control at UC Riverside under the leadership of H.S. Smith and P. DeBach as is referenced in Stern et al,. 1959, The Integrated Control Concept, *Hilgardia* 29 (2): pg 81-99.

48. 50 YEARS OF INTEGRATED CONTROL CONCEPT: THE ROLE OF LANDSCAPE IN IPM

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The concept of integrated control provided the opportunity for thinking larger than managing just individual insect pests on a crop. It opened the door for considering the cropping system and the ecological interactions between pest, crop and prey. After the publication of the seminal paper, Dr. Stern continued to expand this concept to include not only the field and the farm, but also ecosystem in which the management site was embedded. During the late 1960's Dr. Stern realized to effectively and economically manage *Lygus hesperus* in cotton, it is necessary to understand the role of surrounding cropping systems. In series of field studies and publications, he outlined the principles of area wide management for Lygus in San Joaquin Valley cotton. This presentation will pick up the story and provide examples of the continued influence he and colleagues have had on IPM.

49. 'INTEGRATED CONTROL', MEASURING POPULATIONS AND PREDICTING OUTCOMES IN THE COTTON WHITEFLY SYSTEM

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Stern et al. (1959) outlined the fundamental elements of an integrated control program to include a sampling program to measure pest population dynamics, knowledge of the relationship between pest abundance, crop damage and economics represented by the economic injury level (EIL), and an understanding of underlying ecology and population dynamics of pests and natural enemies in the system. The whitefly, *Bemisia tabaci* biotype B, invaded the southwestern US in the late 1980's and precipitated outbreak populations in cotton and other crops during the first half of the 1990's. Development of quick and reliable sampling methods and effective action thresholds were the initial steps taken to support "Supervised Control" and stabilize the system. This presentation focuses on the development of these key tools that support decision making and population prediction, and how they interact with the foundational elements of IPM as it is practiced in Arizona cotton today.

50. 'INTEGRATED CONTROL', CHEMICAL AND BIOLOGICAL COMPATIBILITY IN THE COTTON WHITEFLY SYSTEM

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In their seminal 1959 work, Stern and colleagues outlined the 'Integrated Control' concept within a rich context that survives today in our current-day IPM programs. Their focus was on integration of chemical and biological controls to maintain key pests below economic injury levels. Their insights into the ecological underpinnings of pest control systems were decades ahead of their time during a period when problems with chemical control were becoming more and more apparent. Their basis for integration was the use of selective insecticides in concert with biological and other natural controls. This presentation will detail the highly successful and integrated approach to management of whiteflies (*Bemisia spp*.) in desert cotton over the last 13 years, highlighting the specific chemistries used, their impact on non-target organisms, and the intricate balance among mortality agents that can lead to long-term suppression of this target pest.

51. IPM FOR FRESH-MARKET VEGETABLES IN THE DESERT SOUTHWEST: ARE WE THERE YET?

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In originating their concept of integrated control, Stern et al. (1959) clearly recognized the economic realities and environmental consequences of insecticide use in agricultural production. They logically argued that selective insecticide use should only be attempted after it has been determined that insect control with naturally occurring biotic agents is not capable of preventing economic damage. In essence, chemical control should complement biological control. They concluded their seminal paper however by emphasizing that integrated control will not work in crops where natural enemies are inadequate or where economic thresholds are too low to rely on biological control.

It is no surprise then that growers of high-value fresh-market vegetable crops in the desert southwest rely almost exclusively on insecticides to control a complex of mobile, polyphagus pests. Because leafy vegetables are short season annual crops with little or no tolerance for insect contamination or damage, biological control is generally unacceptable. High expectations from consumers for aesthetically appealing produce free of pesticide residues further forces vegetable growers to use chemical control tactics that are not only effective, but safe. Integrated pest management (IPM) programs developed for lettuce and other leafy vegetables have largely been designed to reduce pest problems and economic losses, as well as mitigate the environmental hazards associated with chemical control in the past. Fundamentally, most of these programs are based on the principles found in the "Integrated Control Concept" and stress the importance in understanding the agroecosystem, the need to sample for pest status and use action thresholds for cost-effective insect control. More recently, IPM programs are utilizing "softer" chemicals that are selectively efficacious against specific pests and primarily aimed at reducing insecticide resistance and occupational risks, rather than preserving natural enemies.

This presentation will examine the influence that the "Integrated Control Concept" has had on IPM in desert vegetable crops, some of the challenges faced by growers in adopting these programs, and how they can be improved for the next generation of vegetable producers and pest control advisors.

52. THE INTEGRATED CONTROL CONCEPT AND MODERN DAY INTEGRATED PEST MANAGEMENT, A CASE STUDY IN TABLE GRAPES

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The 1959 Hilgardia publication entitled "The integration of Chemical and Biological Control of the Spotted Alfalfa Aphid – The Integrated Control Concept" primarily dealt with integrated pest management in alfalfa hay. Alfalfa grown for hay continues to be a relatively low value crop that is sold locally. The commodity is characterized as one having low labor requirements, a long storage life, and an arthropod pest complex in which virtually all species are at an equilibrium level below what is considered the economic injury level. Cosmetic damage from arthropods is not a concern.

How do the principles outlined in the Integrated Control publication apply to pest management in table grapes? Fresh market grapes are a high value commodity characterized by intense labor requirements, relatively short storage life, and are exported throughout the world. The population equilibrium levels of many grape pests (leafhoppers, mealybugs, grape phylloxera, sharpshooters, and black widow spider) are above the economic damage level. Three pests (sharpshooters, vine mealybug, and black widow spider) are considered severe pests and annually require chemical intervention if present in the vineyard.

This presentation examines the principles elucidated in the Stern et al paper as they apply to table grape production. These include establishment of economic thresholds, quick and accurate sampling methods, selective insecticides, and use of biological control. I also examine the concept of Supervised Control as it is currently being used in the crop.

When these points are closely studied, Integrated Pest Management in Table Grapes can be considered high on the pest management continuum and those principles outlined in the Stern et al paper are still applicable.

53. THE CHALLENGES OF IMPLEMENTING IPM INTO TRADITIONALLY PESTICIDE-INTENSIVE VEGETABLE CROP SYSTEMS

Marshall W. Johnson

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Vegetables are historically some of the most pesticide-treated cropping systems in conventional agriculture. Because of this, pesticide resistance is frequently seen in the primary and secondary arthropod pests in these systems, and the effectiveness of biological control agents is usually nil. Over the last 30 years, there has been some

progress in reducing pesticide treatments in vegetables via the implementation of IPM strategies and tactics. The establishment and adoption of economic thresholds has enabled growers to limit the frequency of pesticide treatments, thereby opening the door for the use of natural enemies. The use of economic thresholds has forced the development and use of monitoring tools so that treatment sprays can be delivered at the optimal times. More effective and environmentally friendly compounds have permitted a reduction in the amounts applied per acre and often helped conserve effective natural enemies. It is important to recognize that the inability to successfully manage common pest species is not always due to the limitations of the tactic being implemented, but may have its origins in human behavior. The failures to learn, anticipate, and adapt may commonly contribute to human failure to control pest species that should be easily managed. These concepts and ideas will be discussed using a variety of examples from numerous crop systems and associated pests.

54. INTEGRATED CONTROL: THE PRECURSER FOR INTEGRATED PEST MANAGEMENT AND INTEGRATED BIODIVERSITY MANAGEMENT

L. E. Ehler

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In 1959, four University of California entomologists put forth the concept of Integrated Control, which was defined as "applied pest control which combines and integrates biological and chemical control." Although Integrated Control as originally formulated had a relatively narrow focus (i.e., insect pests), it was eventually broadened to include multiple suppressive tactics for all classes of pests, giving rise to the modern concept of Integrated Pest Management (IPM). The term "integrated" is key, for it implies incorporation of natural enemy/antagonist levels into decision-making, and use of compatible, non-disruptive tactics that preserve these agents. Integration can be viewed as either vertical (i.e., within a class of pests) or horizontal (i.e., among classes of pests). The lack of integration has been one of the major impediments to the implementation of IPM in agriculture. Integrated Biodiversity Management (IBM) seeks to reconcile the goals of IPM and those of conservation biology. An example of IBM involving hedgerows adjacent to tomato fields in Northern California will be discussed.

55. SAMPLING AND ACTION THRESHOLDS IN PERENNIAL CROPS IPM, MYTH AND REALITY

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One of the most fundamental factors distinguishing IPM from pest control is the decision process before an action is taken to prevent unacceptable damage. In the case of

pesticide use in an IPM program, they should in concept be used only after monitoring indicates they are needed according to established control action guidelines. For a number of perennial crop pests, special techniques and sampling procedures have been developed to improve the accuracy of monitoring activities. Sampling can be used for pest detection as well as to quantify densities of pest and beneficial populations. Control action thresholds are intended to reflect the population levels that will cause economic damage. In theory, they are based on considerations that include cost of pest control, crop value, and damage anticipated by a given density of the pest. In practice, many guidelines do not involve numerical thresholds, but instead are based upon history or other factors. This is certainly acceptable depending on knowledge of the pest and its local history. The use of sampling and action thresholds in IPM of perennial crops is explored in theory and practice.

56. LANDSCAPE LEVEL APPROACHES TO IPM: MATCHING MANAGEMENT TO SCALE

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Management of pest species on a local scale has long been the one of the cornerstones of IPM. Approaching decision making with locally generate information has often produced commercially acceptable outcomes with minimal intervention. More recently, people have questioned whether all processes or problems are best approached at a local scale. Examples of successful management of single species for specific crops on an areawide basis such as codling moth or pear psylla in pome fruits are supporting potential shifts in our focus to larger landscape management units. European and US researchers have started to advocate for planning on a landscape level as datasets continue to be develop which illustrate the impacts of regional structure and complexity on overall pest levels, natural enemy community structure, and natural enemy impacts on key species. The rationale for landscape level management clearly needs to be tied to the processes and problems that are driving the issues, e.g. gene flow within and between habitats types in resistance management or the effects of pool size and proximity of natural enemies in native habitats to agricultural settings. The effects of habitat fragmentation, proximity, and management scale will be addressed using examples from the literature as well from experimental data from a variety of cropping systems including tree crops and sunflower habitats. Using wild and agricultural sunflower systems as one model, the effects of wild sunflowers or other systems (e.g. riparian) on natural enemy community structure and diversity in agricultural sunflower fields will be illustrated. Both levels and species composition will be shown to be a function of the distance and type of habitats surrounding agricultural sunflower fields. Similarly, the efficacy of selective management programs can be enhanced as the scale of the program increases. In spite of the obvious economic barriers to implementation, a case will be presented for

future management of specific pests (e.g. navel orangeworm) on larger non-traditional scales.

57. EVOLUTION OF IPM ON AVOCADOS IN CALIFORNIA IN THE CONTEXT OF INVASIVE ARTHROPODS

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Avocado production in California (ca. $300 million crop value) was a fairly simple matter until the appearance of persea mite, *Oligonychus perseae* Tuttle, Baker and Abatiello, ca. 1990 and avocado thrips, *Scirtothrips perseae* Nakahara, in 1996. Prior to that, insects and mites were under effective biological control and pesticide use was rare. Persea mite remains a sporadic pest and avocado thrips can be quite severe some years, causing an estimated $50 million in crop loss in 2006. Until 1 February 2007, Mexican avocados were not allowed entry into California. A survey of fruit entering California from Mexico was conducted September 2007 – April 2008. An estimated 67 million Mexican 'Hass' avocados entered California over this period. Based on samples from 140 trucks containing ca. 15.6% of this volume of fruit, we estimate that ca. 47.6 million live sessile armored scales and an additional 20.1 million live eggs and crawlers were imported. We found eight species of armored scales in the samples, seven of these are not believed to occur in California; 89.3% of the live scales were *Abgrallaspis* sp. A, a species that is in the process of being described and named. If one or more of these armored scales were to establish in California, it is unknown to what degree endemic parasitoids might control the scales. Chemical control on the hillsides where more than 90% of California avocados are grown would be problematic. Avocado joins a list of several commodities in California that are struggling to deal with invasive arthropod pests. This is a serious problem that is being amplified by the easing of importation restrictions as part of international free trade agreements, and decreasing support for quarantine enforcement in exporting countries and points of ingress in California.

58. BIOLOGICAL CONTROL AS A COMPONENT OF IPM IN PERENNIAL CROPS

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Perennial crops provide one of the most favorable environments in which natural enemies can contribute to the biological control of both primary and secondary arthropod pests. This is evidenced by the fact that over the last century biological control importations have been substantially more effective in tree fruit orchards than in any other agricultural

setting. Despite this and the historical intention that biological control should be the cornerstone of effective IPM, the last 50 years of pest management in perennial crops has largely continued to be based on a reliance on pesticides. I will begin by highlighting the importance that both natural enemy introductions and enhancement of indigenous natural enemies has played in perennial crops over this period of time. Subsequently, I will highlight the future opportunities and limitations for biological control in perennial crops, now that IPM must be in compliance with new standards regarding food, water and air quality.

59. MATING DISRUPTION AS A CENTRAL COMPONENT OF IPM PROGRAMS IN PERENNIAL CROPS

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Pheromone-based mating disruption is among the most effective biopesticides for managing codling moth, oriental fruit moth and several other lepidopteran pests of perennial crops. An estimated 160,000 hectares worldwide, including 77,000 ha in North America, are treated with pheromone to control codling moth alone. This novel approach entails dispensing synthetic codling moth sex attractant into a crop so as to interfere with mate-finding, thereby controlling the pest by curtailing the reproductive phase of its life cycle. At present mating disruption is largely achieved through the manual application of pheromone release devices at a rate of 500-1000 sources per hectare. Substantial efforts have been invested in other formulations to make the technology more cost effective and efficacious. Plastic flakes, chopped fibers and microencapsulated formulations have been developed that allow the pheromone to be sprayed on the crop either by ground or air. An intriguing pheromone-based approach entails the formulation and release of insect sex attractants via aerosol-emitting devices that are deployed at densities of only 2-5 per ha. Regardless of the formulation used, mating disruption works best if initial pest density is low. Thus, the management approach is to use disruption in concert with supplemental insecticide sprays as needed. We have been exploring ways to achieve mating disruption of tortricid moth pests that provides outstanding disruption regardless of pest density and without the need for supplemental insecticides. This work is founded on recent studies examining the mechanisms underlying mating disruption. This paper will review the development of mating disruption for pests of perennial crops, examine the constraints to using this tactic, and explore the potential for improved disruption formulations and increased adoption of this environmentally sound IPM tactic.

60. NOVEL REDUCED RISK INSECTICIDES AS A COMPONENT OF IPM PROGRAMS FOR MAJOR PESTS OF PERENNIAL CROPS

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The EPA decision to phase out use of azinphosmethyl signals the end of this product's use by fruit growers. The last year apple and pear growers will be allowed to use azinphosmethyl is 2012, but there is a gradual reduction in the amount of the product that can be used each year prior to 2012. The EPA has registered several novel insecticides for use on tree crops that they classify as reduced risk or organophosphate (OP) alternatives. The large number of alternatives to OPs is a blessing and a curse. OP alternatives are much safer from a human perspective, and in most cases environmentally, than products they are designed to replace. However, they are also more expensive, have a narrow spectrum of activity, tend to be less efficacious, have shorter residues, target different life stages, and are more subjective to operational factors than the OPs. The shear number of new choices of products for pest control in tree fruit greatly increases the complexity of the decision making process. Understanding how novel insecticides fit into an apple IPM program provides insights into the challenges and opportunities facing other perennial cropping systems. This presentation reviews differences among some of the novel insecticides registered on apple for management of key pests and how this information is being integrated into an education/outreach program for Washington apple producers. Other parts of this symposium address the concerns and hopes that novel insecticides bring to perennial cropping systems, such as, the potential for resistance development to new insecticides, disruption of biological control, and new decision aids to help growers and consultants deal with the complexity of choosing the right product for the right time and pest.

61. IMPACT OF NOVEL REDUCED RISK INSECTICIDES ON NON-TARGET ARTHROPODS IN PERENNIAL CROPPING SYSTEMS

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New classes of insecticides are becoming available for perennial cropping systems. The use of these products is increasing as older products are regulated out of the marketplace or are no longer effective because of insecticide resistance in targeted pest populations. Issues of performance have arisen for some of these newer products, especially with regards to secondary-pest outbreaks. Conflicting results and observations indicate that some uses may flair non-target pests by disrupting natural enemies, or not. It is possible that some new reduced risk insecticides are not as "soft" as previously thought.

62. INSECTICIDE RESISTANCE: A MAJOR OBSTACLE FOR THE SUCCESS OF IPM PROGRAMS IN PERENNIAL CROPS

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The evolution of insecticide resistance by insects threatens human welfare through its impact on crop protection and disease transmission. It is a major problem in situations, such as orchards, where pest management relies heavily on insecticides. The introduction of broad-spectrum synthetic insecticides has resulted in a rapid increase in resistance. Until 1946 only 12 cases of insecticide resistance were reported including the first widely recognized case of insecticide resistance reported in early 1900s, when lime sulfur failed to control San Jose scale on Washington State apples. Since then, insecticide resistance has increased dramatically with more than 500 species of insects reported as evolving resistance to one or more insecticides. As alternatives to broad-spectrum insecticides, several reduced risk insecticides have been registered for codling moth and leafroller control since the late 1990s. We found evidence of correlated cross-resistance between organophosphate insecticides and methoxyfenzide in leafrollers. Resistance to spinosad in leafroller populations was documented only 6 years after it was registered. In recent field surveys we found evidence of cross-resistance between spinosad and spinetoram, reduced susceptibility to emamectin benzoate for the first time, and low levels of resistance against chlorantraniliprole, even before its registration, in the leafroller, *Choristoneura rosaceana.* The LC_{50} values of *C. rosaceana* for chlorantraniliprole and spinetoram were significantly increased after a few generations of selection in the laboratory. Based on our studies with *C. rosaceana*, we conclude that the risk of resistance evolution against recently registered insecticides with novel modes of action exists, and that now is the best time to implement resistance management strategies to delay the evolution of resistance and conserve as long as possible the susceptibility of the key tree fruit pests to the novel reduced risk insecticides.

63. EVOLUTION AND IMPLEMENTATION OF DECISION SUPPORT SYSTEMS IN PERENNIAL CROPS

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IPM programs can be thought of as a method of pest management that substitutes information-based complexity to reduce damage compared to simple control tactics that are applied on a repetitive basis regardless of pest pressure or timing. In recent years, we

have seen a marked increase in the complexity of the IPM programs in perennial crops because of: (1) legislative mandated changes in pesticide availability, (2) development of new control tactics such as mating disruption, (3) increased knowledge of pests and natural enemy biology, and (4) introduction of new pests or the rise of previously uncommon pests. In this presentation, we focus on decision support systems (DSS) that have evolved over time from simple tabular output, to expert systems based on stringent "rules" that produce , and finally to information systems that synthesize the background data necessary for a pest manager to implement modern successful IPM programs. In addition, we provide survey data taken from the Washington State University Decision Aid System (WSU–DAS) for tree fruits that provide details on user acceptance and usage patterns of that system.

64. BEHAVIORAL RESISTANCE EXHIBITED BY HOUSE FLIES TO PESTICIDES

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Pesticide susceptibility assays often measure insect survival to a forced exposure to a pest control product or isolated active ingredient. These tests provide a measure of the physiological resistance of an insect population (target site insensitivity, altered enzyme activity, etc…) but do not measure behavioral resistance. Behavioral resistance can be described as the ability to detect and avoid a lethal dose of pesticide. Over time, pest populations may develop an avoidance behavior limiting their contact with a toxicant or pesticide. This behavioral resistance may work in concert with or independently of physiological resistance. House flies are typically managed using insecticidal baits and persistent pesticide applications to fly resting sites. House fly populations in southern California were tested for both physiological and behavioral resistance to two commonly used active ingredients (imidacloprid and permethrin). While some physiological resistance was evident, the behavioral resistance was significant and helped to explain recent field failures with these active ingredients.

65. A COMPARISON OF DEMAND™ CS, TERMIDOR™, TRANSPORT™ GHP FOR THE URBAN PEST MANAGEMENT OF ARGENTINE ANTS (Hymenoptera: Formicidae) IN SOUTHERN CALIFORNIA

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Argentine Ants are considered by many urban pest management professionals (PMP's) to be the top economic pest (Klotz et.al, 2002) in southern California, and is ranked first among insect pests found in urban environments in North America (Holway 1999). Argentine ant foragers are most abundant between the months of May and November, but can be found throughout the year in California (Suoja et. a l2000). In addition, with no hostility between adjacent colonies, their colonies are polygynous and largely interconnected.

The objective of this study was to evaluate the efficacy of chemical applications around structures to manage infestations. Using four buildings for each treatment; 1) Transport™ GHP with active ingredients Bifenthrin and Acetamiprid (FMC); 2) Demand CS with active ingredient lambda-cyhalothrin (Syngenta); 3) Termidor with active ingredient fipronil (BASF) and 4) controls, each was applied per label. Percent effectiveness for each treatment at 56d post treatment was Demand 94.05%; Termidor 93.55%, and Transport 98.96%.

Holway, D.A. 1999. Competitive mechanisms underlying the displacement of native ants by the invasive Argentine Ant. Ecology 80(1): 238-251.

Klotz, J. H., M. K. Rust, H. S. Costa, D. A. Reierson, and K. Kido. 2002. Strategies for Controlling Argentine Ants (Hymenoptera: Formicidae) with Sprays and Baits. J. Agric. Urban Entomol. 19: *85-94.*

Suoja, S., Garcia-Rubio, Salvador Garcia-Rubio, Gee Chow, and Vernard R. Lewis, Ph.D. 2000. Ant Behavior Impacts Barrier Efficacy. Pest Control, 68 (10): 65, 66, 68, and 72.

66. RECRUIT™ HD - A PARADIGM SHIFT IN THE EVOLUTION OF TERMITE BAIT TECHNOLOGY

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The use of baiting for control of subterranean termites (Isoptera: Rhinotermitidae) has changed and improved over many years. The most successful commercial bait product is the Sentricon® Termite Colony Elimination System introduced in the early 1990s and currently marketed by Dow AgroSciences. A new baiting concept utilizing Recruit HD durable bait is being developed and tested throughout the United States which may dramatically change the way in which baits are utilized. Noviflumuron, a benzoylurea chitin synthesis inhibitor, is also the active ingredient in the current Sentricon system and has demonstrated consistent termite colony elimination through numerous research trials and commercial use since 2005. Over 100 structures across the U.S. are currently involved in research trials with this new concept. Summaries of these sites as well as laboratory findings of efficacy, palatability and durability will be presented. Current data support this concept as a revolutionary new method of termite control with reduced use of pesticide active ingredient compared to traditional liquid termiticide treatments.

67. UNBAISED PISTACHIO PREFERENCE BY THE NAVEL ORANGEWORM

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Egg traps are invaluable IPM tools for management of navel orangeworm (NOW), *Amyelois transitella*, a major pest of almonds, pistachios, and walnuts in California. These traps baited with almond press cake or crude almond oil assist in determining the timing for effective insecticide treatment or other means to decrease populations and, consequently, crop damage. One of us (G.M.L.) hypothesizes that female NOW prefers pistachios over almonds and walnuts for oviposition. While testing this hypothesis in indoor bioassays we were surprised to observe a clear preference for pistachios, in marked contrast to what is reported in the literature. In an end-of-year scientific discussion between our research groups, it transpired that similar choices tests, independently conducted in the field (by B. H.), mirrored our laboratory findings. To develop new chemical lures for egg traps that may be used throughout the season, we are investigating by gas chromatography with electronantennographic detection (GC-EAD)

and GC-mass spectrometry (GC-MS) the pistachio-derived constituents mediating oviposition preference.

68. AMBIENT ALMOND VOLATILES FROM GEOGRAPHICALLY DIFFERENT ORCHARDS AND THEIR RELATIONSHIP TO NAVEL ORANGEWORM

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Several studies have investigated the various non-volatile and volatile components of various plant parts; however, the volatile organic compound (VOC) emission of several cultivars in an almond orchard has not been studied. This aspect is particularly relevant to research concerning the navel orangeworm (NOW), a major insect pest of almonds and other tree nuts. Despite several flights of NOW, the identification of background VOCs, or their potential correlation to NOW attractancy, has not been addressed. The ambient VOC emission of two almond orchards was collected during the months of May-July via a large-scale volatile collection system developed specifically for tree-nut orchards. The collected VOCs were indivdually subjected to electroantennographic (EAG) bioassy; several VOCs exhibited positive EAG signals from both male and female NOW moths. Synthetic blends mimicing the natural ambient VOC makeup were formulated and evaluated for efficacy as background VOC mixes for NOW attractants.

69. KONTOS GREENHOUSE AND NURSERY INSECTICIDE/MITICIDE: PESTS CONTROLLED AND STRATEGIES FOR USE

R. Royalty, T. Macom, J. Dobbs, J. Michel, R. Lindquist

Kontos greenhouse/nursery insecticide was launched in the spring of 2009. The new mode of action (lipid biosynthesis inhibition) suggests that Kontos will be a powerful tool for management of sucking insect pests. Results of recent testing against a variety of insect and mite pests are presented. Proper use of the product is discussed.

70. NON-TARGET PLANT USE BY *LARINUS CURTUS*: HOST EXPANSION OR OPPORTUNISTIC BEHAVIOR BY THISTLE BIOCONTROL AGENT?

Steve L. Clement

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Larinus curtus Hochhuth (Coleoptera: Curculionidae) was first introduced into western United States from Greece for the biological control of yellow starthistle (YST), *Centaurea solstitialis* L., in 1992. The discovery of *L. curtus* adults in the open flowerheads of safflower (SF), *Carthamus tinctorius* L., near Lewiston, Idaho in 2007 suggested this weevil might be expanding its host range to include a non-target crop species closely related to YST. In 2008 field plots near the 2007 observation site, 92 *L. curtus* adults fed in open SF flowerheads (pollen feeding and minor feeding on corolla tubes). No eggs were found in the ovarioles of 19 pollen-feeding females. No eggs, larvae, or evidence of larval feeding were detected in 39 tagged SF capitula, and no adults emerged from approximately 7,135 post-flowering SF capitula. These collective results are not indicative of an expanding developmental host-range of *L. curtus*. Also, they are consistent with pre-release host-specificity results.

71. APHIDS ASSOCIATED WITH RHUBARB IN ALASKA

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Culinary rhubarb, *Rheum* spp is one of the priority crop species curated at the USDA Agricultural Research Service, Subarctic Agricultural Research Unit (SARU) in Palmer, Alaska. The Palmer site acts as the primary rhubarb repository for the USDA, ARS, National Plant Germplasm System. The SARU rhubarb collection has 41 accessions; some infected with Turnip mosaic virus (TuMV). TuMV spreads mechanically from plant-to-plant, and by aphids. The TuMV has a large plant host range and has a worldwide distribution, but little is known about the insect fauna associated to *Rheum* spp. Furthermore there is no consensus on the aphid species associated with this plant and there are no known published reports on aphids associated to rhubarb in Alaska. This work was initiated to identify the aphids associated to commercial rhubarb in Alaska and identify the potential vectors of TuMV. Research conducted from 2003 to 2007 in the rhubarb producing areas of Alaska resulted in the identification of 20 aphid species

associated with commercial rhubarb production. Only twelve of the twenty species associated with the crop were recovered by hand collecting. Three of the twelve species collected by hand, *Hayhurstia atriplicis*, *Macrosiphum euphorbiae*, and *Ropalosiphum* spp. represented 77.8% of the total number of aphids collected by that method. *Chaitophorus* and *Ropalosiphum* were the most abundant genera in Fairbanks (34%) and Palmer (30%) respectively. To our knowledge, this report represents the first study of aphids from rhubarb in Alaska.

72. IMPROVED FRUIT FLY DETECTION METHODS WITH FARMA TECH SOLID MALE LURE AND INSECTICIDE DISPENSERS

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Methyl eugenol (ME) and cue-lure (C-L) traps to detect fruit flies (Diptera: Tephritidae) on the U.S. mainland were tested with liquid and solid lure-insecticide formulations under Hawaiian weather conditions against small populations of oriental fruit fly, *Bactrocera dorsalis* (Hendel) and melon fly, *B. cucurbitae* (Coquillett), respectively. Captures with the Hawaii fruit fly Area-Wide Pest Management (AWPM) trap with liquid lures and DDVP (2, 2-Dichorovinyl dimethyl phosphate) insecticidal strips, compared favorably with those for the Jackson trap with liquid lure and naled (the Florida standard). In subsequent tests, captures with solid Farma Tech wafer dispensers with ME or C-L and DDVP placed inside Jackson and AWPM traps were equal to those for a Jackson trap with a naled and lure mixture currently used for detection of ME and C-L responding fruit flies in Florida. From a worker safety and convenience standpoint, Farma Tech ME and C-L solid wafers with DDVP would be more convenient and safer to handle than current liquid lure and insecticide formulations (e.g. naled) used for detection programs in Florida and California.

73. NON-COMMERCIAL PRACTICES TO CONTROL CITRUS THRIPS IN CALIFORNIA BLUEBERRIES

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Citrus thrips, *Scirtothrips citri* (Moulton), has recently become a significant pest of blueberries in the San Joaquin Valley of California. Feeding by the citrus thrips stunts plant growth, which can negatively impact the crop yield the following spring. Insecticide treatments with spinosad are currently the management method of choice. However, alternatives are needed, especially for use in organic production. From 2006 to 2008 we conducted multiple trials that evaluated alternatives to pesticides, including high pressure water treatments, overhead sprinklers, and green lacewing, *Chrysoperla rufilabris* (Burmeister), releases. High pressure water treatments suppressed citrus thrips in all three years of our trials, but reductions were relatively minimal compared to insecticide treatments. Overhead sprinklers reduced citrus thrips over time and promoted shoot growth as well. Studies on green lacewing releases illustrated no differences from the control in all plots. We found that high pressure water can impact citrus thrips densities, and could possibly be used with other organic products to lower densities in organic blueberries.

74. EVALUATIONS OF POST HARVEST TREATMENTS FOR VINE MEALYBUG IN TABLE GRAPES

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During the past few years there has been a lot of debate over the value of post-harvest treatments for vine mealybug, *Planococcus ficus* (Signoret), in table grapes. In order to help determine the value of post-harvest treatments two field trials were conducted in August 2007 in Kern County. Seven registered insecticides plus an untreated check were included in the trials and multiple evaluations were made in the fall of 2007 and spring of 2008. Data showed that post-harvest treatments can provide significant reductions in mealybug densities the following spring. The greatest control was provided by the lipid biosynthesis inhibitor Movento, followed by Sevin and the grower standard Lorsban. This presentation will further discuss these results and the impact they can have on the California grape industry.

75. NUTRITIONAL ECOLOGY AND FORAGING BEHAVIOR OF *MANDUCA SEXTA*

Mary A. Sorensen, Nelson S. Thompson, Richard A. Redak

In the laboratory, it has been shown that *Manduca sexta* (Lepidoptera: Sphingidae), when offered a choice of two artificial diets, will eat selectively from each of the two diets to reach a nutrient target, a particular ratio of protein and carbohydrate. We examined whether *M. sexta* feeding on plants rather than on artificial diet will regulate protein and carbohydrate intake to reach an optimum nutrient target by eating young, protein-rich leaves mixed with older, carbohydrate-biased foliage. Additionally, whereas previous nutrient target research involved relatively high levels of nutrients, we examined diet choice and nutrient intake regulation using a defined diet with overall nutrient concentrations comparable to levels found in *M. sexta* host plants.

76. 2008 FIELD RELEASES OF *PSYTTALIA* cf. *CONCOLOR* FOR BIOLOGICAL CONTROL OF OLIVE FRUIT FLY IN CALIFORNIA

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The parasitoid *Psytallia* cf. *concolor* (Szépligeti) was reared on sterile Mediterranean fruit fly larvae at the USDA-APHIS-PPQ, Petapa Quarantine Laboratory in Guatemala and shipped to the USDA-ARS, Parlier for biological control of olive fruit fly, *Bactrocera oleae* (Gmelin), in California. Improved techniques were developed to increase parasitoid production and to enhance survival during shipment by two-day air and ground freight. An average of about 16,000 parasitoids was received in Parlier per week between September 2008 and January 2009. The parasitoids were released in olive trees with fruit infested with olive fruit fly in southern California at Rancho Bernardo; in the San Joaquin Valley at Strathmore and Lemon Cove; in the Sacramento Valley at Lodi, Orland, and Oroville; and in coastal areas at Solvang, Cayucos, Paso Robles, San Jose, and Napa. In most locations, subsequent generations of the parasitoid were collected from olive fruit fly in post-release samples of fruit. Less olive fruit fly larvae were collected from fruit in trees that were exposed to parasitoids, than in fruit from trees that were not exposed. More parasitoids were collected from fruit infested with olive fruit fly in the upper canopy of trees than in the lower canopy.

77. ENHANCING BIOLOGICAL CONTROL OF RUST MITES IN VINEYARDS

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Short Shoot Syndrome (SSS) causes economic crop losses in Pacific Northwest and cool coastal California vineyards of the United States. Crop losses can be as high as 50% in vineyards that are severely affected. Apart from direct crop losses, vine architecture may also be negatively affected due to shoot necrosis. It is believed that rust mites, *Calepitrimerus vitis* (Nalepa 1905) (Acari: Eriophyidae), contribute to SSS damage. Mite outbreaks occur due to a combination of environmental conditions and fungicide spray regimes. For this reason, a focused research effort to develop integrated control practices for eriophyid mites, powdery mildew, and conservation biological control of pest mites is essential for sustainable grape production. Developmental pest mite data will be used to better time miticide sprays, while minimizing the impact on key predatory mites. In order to investigate the impact of often-used pesticides, trials were conducted in two mite-infested vineyards during 2007 and 2008. Several spray regimes using different combinations of fungicides were trailed throughout the season. Data from 2007 and 2008 shows increased abundance of a key predatory mite in blocks which received reduced sulfur applications. Field trials are supplemented by laboratory experiments in order to verify trends found in our field work.

78. NOW EGG TRAPS: EFFECT OF BAIT ATTRACTIVENESS ON DETECTION AND PRECISION IN THE FIELD

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The navel orangeworm, *Amyelois transitella* (Walker) (NOW), is the principal insect pest of California almonds and pistachios, and an important pest in walnuts and figs. A pheromone lure sufficiently stable for field use is not available for this species. Currently the timing of pesticide treatments in almonds and pistachios are informed by counts of eggs on egg traps containing medium on which NOW females oviposit. Here we examine the distribution of egg counts on pairs of traps, on the same tree, filled with ground almonds or pistachios. Plots comprised grids of 30 such trees over a 4.5 ha plot, with two plots located in adjacent almonds and pistachios orchards at two locations. We examined, at hypothetical critical densities, the number of traps needed for 20% and 10% precision using either trap means or binomial proportions (i.e., the proportion of traps with eggs on them). These data indicate that fewer pistachio-baited traps than almond-baited traps are needed to reach the desired precisions using either mean egg numbers or binomial

sampling, but that the combination of pistachio bait and binomial sampling is particularly advantageous.

79. SUMMER SURVIVAL OF ADULT AND IMMATURE OLIVE FRUIT FLY IN THE SAN JOAQUIN VALLEY, CALIFORNIA

Hannah Nadel[1], Marshall W. Johnson[1], Kent M. Daane[2] and Xing-geng Wang[1]

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In the San Joaquin Valley, olive fruit fly (*Bactrocera oleae* [Rossi]) lacks host fruit for up to four months in spring and early summer, while high summer temperatures may further prevent recruitment to adult populations. When temperatures cool in fall, viable larval infestations increase rapidly in non-commercial olives, suggesting that adult flies are already present, and that temperatures are more favorable for larval survival. We therefore studied effects of summer temperatures on immature stages in olives in temperature-controlled cabinets and determined whether flies emerging in spring can survive in field cages until autumn. Egg mortality within fruit was 100% within a few hours of exposure to 38˚C, and all instars had higher mortality with increasing heat duration and intensity. About 50% of female flies caged in April and June survived 4 – 5 months. Summer heat likely kills most or all *B. oleae* eggs and larvae in the San Joaquin Valley, while adult females are potentially long-lived and, with sufficient food and water, can survive from spring to fall.

80. WASHINGTON STATE APPLE PEST MANAGEMENT TRANSITION PROJECT

Keith R. Granger and Jay F. Brunner

Washington State University, Tree Fruit Research and Extension Center, Wenatchee, WA

The Pest Management Transition Project (PMTP) was funded by the Washington State Legislature for two years ($550,000 for 07-09 biennium) to accomplish three objectives:

1. To enhance understanding of new IPM technologies through educational programs and communication of research-based knowledge.
2. To increase adoption of new IPM technologies through sharing information on successes and failures and communicating with all stakeholders on project progress.
3. To document changes in practices, attitudes, and perceptions of growers, farm workers, and stakeholders.

The three objectives were addressed in 2008 through Implementation Unit (IU) meetings, printed materials, and web-based products. Fourteen IUs, distributed geographically

across the principal apple production regions of Washington State, were established in 2008. The IUs involved 192 participants representing over 42,600 Washington apple acres. A PMTP handbook was developed to provide reference and support at educational and informational events and IU meetings. Three field days were held to share the PMTP knowledge and experiences with a broader audience of the tree fruit industry. Ten newsletters addressing seasonal IPM topics were distributed via mail and email. More information about the PMTP, archived additions of the newsletters, and the PMTP handbook can be found by visiting the PMTP web site (http://pmtp.wsu.edu).

81. SPIDER COLONIZATION OF CALIFORNIA VINEYARDS: THE ROLE OF AERIAL VERSUS GROUND DISPERSAL

Brian Hogg and Kent Daane

Division of Organisms and the Environment, University of California, Berkeley, CA

Many generalist predators must colonize crops on a seasonal basis from natural vegetation. In this study, we monitored the aerial and terrestrial movement of spiders in California vineyards and neighboring oak woodland, to assess whether dispersal from natural habitat influences spider species composition in vineyards. Aerial traps reflected spider composition in vineyards more than ground traps, suggesting that spiders in vineyards dispersed more by air than over ground. Early in the season, low spider numbers in the vine foliage indicated that few spiders overwintered in the vineyard. Aerial dispersal did not occur primarily in the spring, however, when generalist predators are most likely to be important in pest suppression; instead, numbers of most spider families were highest on aerial traps in mid-summer. Dwarf spiders (Linyphiidae) dominated spider composition on aerial traps but were not abundant in the vine foliage, while other species showed an opposing pattern, indicating that aerial dispersal capacities were not the only factor that influenced the success of spiders in vineyards.

82. INNOVATIVE GOVERNANCE FOR SUSTAINABLE TRANSITIONS TO NOVEL IPM AND GM TECHNOLOGIES: FROM AUTHORITY TO LEGITIMACY

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New technologies continue being integrated into the farmer's IPM tool portfolio around the globe. Human ingenuity allows for a very broad and exciting range; new seeds, sophisticated chemical pesticides, natural plant oils, IT and sensors, genetically modified crops and many more. The promise has been to improve the quality of foods, reduce environmental impacts and help increase food productivity. But as with any new technology, risks are also associated with the adoption of new tools. In the past, experts such as scientists, academics, regulators and industry managers have been in charge of translating new IPM technologies

from private and public labs to farmers around the globe. This model seems to be losing ground; the "lay public" represented by end users and consumers has been gaining influence and seems to be skeptical of the way in which benefits and risks have been allocated in society so far. In this paper we review some evidence from Canada, Mexico, China and Iran; pointing to the need for a broader consultation in the process of new IPM technology design and translation. We argue that successful adoption will depend more on balanced approaches, depending less from the authority of experts and relying more on the views of users and consumers, thus gaining legitimacy. Sustainable technology translation seems to require broader efforts from scientists, industry and regulators to effectively initiate dialogue with key stakeholders in the early stages. Transitions to novel technologies could end up being "kept in the drawer", placing R&D investment and food production at risk, if closer interaction between experts and the general public does not become the norm.

83. REFINEMENT OF IPM PROGRAMS FOR VINE MEALYBUG IN SAN JOAQUIN VALLEY TABLE GRAPES

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Vine mealybug has become the most significant insect pest of table grapes in the lower San Joaquin Valley. Even a small number of mealybugs can cause significant problems due to zero-tolerance policies for insects in fresh-market fruit. For the last several years many efforts have been underway to develop effective management programs for this pest. The purpose of this project was to take existing programs, which were primarily developed in Fresno County, CA raisin grape vineyards, and determine how they can be refined for improved IPM in table grapes in the lower San Joaquin Valley. This paper will discuss findings from the 2008 research season. This includes information on regional nuances in vine mealybug biology that are specific to the lower Valley, observations regarding differences in how this pest interacts in table grapes compared to wine or raisin grapes, and results from in-season insecticide trials. These trials evaluated existing products such as Lorsban, Applaud and Admire for their affects on vine mealybug and compared that to newer products such as Movento, Clutch, Venom and Platinum. The presentation will conclude with statements regarding how to utilize information from these trials while developing season-long approaches to vine mealybug management.

84. THE DEVELOPMENT AND REGISTRATION OF LORSBAN® ADVANCED A NEW AND INNOVATIVE PRODUCT FOR PEST CONTROL

Boris A. Castro[1], Luis E. Gomez[2], Barat Bisabri[3], Ray E. Boucher[2], Brian L. Bret[4], Brian E. Timmerman[2]

[1]Dow AgroSciences, Fresno, CA; [2]Dow AgroSciences, Indianapolis, IN; [3]Dow AgroSciences, Orinda, CA; [4]Dow AgroSciences, Sacramento, CA

The Dow AgroSciences commitment to research and development continues to provide unparalleled technological advancements and forward-thinking solutions needed to solve pest problems both today and in the future. Lorsban® Advanced is the first chlorpyrifos product to achieve a low-odor, low-VOC (volatile organic compound) in a water-based formulation. Lorsban Advanced represents the end of a multi-year research and development process by Dow AgroSciences, resulting in an innovative product for western agriculture.

85. RE-ESTABLISHING DIAMONDBACK MOTH SUSCEPTIBILITY TO THE SPINOSYNS IN COASTAL CALIFORNIA: A SUCCESS STORY

Jesse M. Richardson[1], James I. Matsuyama[2], Barat Bisabri[3], Anthony M. Shelton[4] and James E. Dripps[5]

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Diamondback moth, *Plutella xylostella* (Linnaeus), is a persistent pest of cole crops in California. Since the 1980s, it has been one of the most damaging insect species along the coast, in particular. The spinosyns are important tools for diamondback moth control worldwide. Five years after its registration in California, spinosad was found to be providing inadequate control of diamondback moth larvae in selected collard fields in the Oxnard Plain. Laboratory testing revealed that this was due to reduced susceptibility of the insect. Dow AgroSciences, LLC, subsequently initiated an aggressive program to restore diamondback moth sensitivity to spinosad. Ten months later, field results and laboratory tests revealed that the insect had returned to full susceptibility. Recurrent laboratory testing and field performance has shown that the Oxnard Plain diamondback moth population has largely retained sensitivity to spinosad and spinetoram. Details of the tactics which brought about this outcome will be discussed.

86. THE OFTEN-OVERLOOKED INVERTEBRATES: MONITORING AND MANAGING SLUGS IN GRASSES GROWN FOR SEED IN OREGON

Amy J. Dreves[1]and Glenn C. Fisher[1]

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Grass seed fields in the Willamette Valley with minimum tillage, reduced field burning, improved field drainage, and increased organic matter are developing persistent slug problems causing greater economic losses in grass seed and rotational crop production. Two prominent slugs causing damage are the gray field slug (*Deroceras reticulatum*) and brown-banded slug (*Arion* spp.). Sampling methods including slug blankets, overnight bait stations and plywood boards were compared to absolute sampling methods (cold water extraction and defined area trapping) for detecting and estimating slug numbers to assist growers and field reps in decision-making for determining treatment need, evaluating control methods, and identifying an accurate and timely procedure. Presence of young neonates, earthworm abundance, seasonal variation in weather including cold temperatures, high winds and moisture, and dry conditions negatively affected numbers of slugs counted; and directly influenced the effectiveness of treatments. Slug counts using blankets were repeatedly higher (58-89%) compared to absolute methods. Mortality of slugs using iron-phosphate pellet formulations did not occur until 3-5 DAT, however feeding greatly declined after day 1 particularly when soil surfaces were dry. Metaldehyde products worked best after active rains. In addition, grazing of sheep and cultivation of land reduced numbers of slugs in field.

87. VECTOR WITHIN-HOST FEEDING PREFERENCE MEDIATES TRANSMISSION OF A HETEROGENEOUSLY DISTRIBUTED PATHOGEN

M. Daugherty, J. Lopes, R. Almeida

University of California, Berkeley

Ecological theory suggests that vector preference for infected versus uninfected hosts can impact dramatically disease prevalence. However, little information exists on how vector behavior interacts with pathogen distribution within hosts to mediate transmission. This may be particularly important for sharpshooter transmission of *Xylella fastidiosa*, an economically important pathogen that is heterogeneously distributed throughout its host plants. We documented *X. fastidiosa* distribution in different parts of mechanically inoculated alfalfa plants. *Xylella fastidiosa* infection rates and populations were much higher near the plant base than at the tops or in the taproot. We then documented the position of two sharpshooter species, the primarily grass-feeding *Draeculacephala minerva* and non grass-feeding *Graphocephala atropunctata*, free to move throughout

entirely caged alfalfa plants. *Draeculacephala minerva* fed primarily on the basal portion of plants, whereas *G. atropunctata* fed primarily at the plant top. Finally, we estimated transmission efficiency of these two species in no-choice trials with individuals caged at either the base or top of alfalfa plants. Both vectors were inefficient when allowed to acquire from the tops of infected plants and were more efficient when confined at the plant base – especially *D. minerva*. These results suggest that vector within-host feeding preferences may contribute strongly to rates of disease spread.

88. ARTHROPOD RESPONSE TO RESIDUE REMOVAL SYSTEMS IN DRYLAND KENTUCKY BLUEGRASS SEED FIELDS OF N. IDAHO

T. Hatten, R. Biggam, J. Johnson-Maynard, D. Thill, K. Umiker, J. Reed, B. Shafii and J. McCaffrey

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Kentucky bluegrass (KBG) is grown for seed on approximately 100,000 acres in the Inland Pacific Northwest (IPNW), accounting for most of the nation's seed production. KBG growers have traditionally burned bluegrass residue to maintain stand productivity and to control pest-related problems including a condition called silver top. However, air pollution resulting from field burning has prompted research into nonthermal systems that rely on mechanical practices to remove residue including raking, baling and mowing. Little is known about how mechanical residue removal practices affect pests or natural enemies. A pitfall trapping study was conducted from 2003 to 2005 in Kootenai Co., ID to determine how the arthropod community responds to four residue removal systems; full-load-burn (FLB), bale-and-burn (BB), bale-mow-harrow (BMH), and bale-mow-harrow-system (SYS). In total, we captured 420,737 arthropods comprised of 20 higher taxonomic groups. The response of natural enemies and pest to treatments was mixed. Catches of Araneae and Opiliones exhibited within-season-variability, and were sometimes elevated in nonthermal- and sometimes in thermal systems. Thysanoptera catch was elevated in BB and FLB while Hemiptera catch was elevated in BMH. Some species of Hemiptera are thought to cause silver top, but we detected no treatment effects on silver top during the study.

89. IMPROVING ALMOND 'MUMMY' SANITATION FOR ENHANCED CONTROL OF NAVEL ORANGEWORM

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Almond mummy sanitation from orchards in winter is essential to control of navel orangeworm (NOW), *Amyelois transitella* (Walker) (Lepidoptera: Pyralidae), a devastating insect pest of almonds. By eliminating mummies (i.e. almonds remaining in the tree after harvest), NOW are stripped of their overwintering 'hotel', thus disrupting their life cycle. A trial was conducted in 'Nonpareil' almonds to determine if dormant applications of variable rates of water prior to shaking will increase the efficacy of the mechanical tree-shaker portion of a mummy sanitation program and hence reduce the per acre costs of the manual poling portion. Results and implications for future mummy sanitation programs will be discussed.

90. ACUTE TOXICITY OF ADULT CODLING MOTH WITH CHLORPYRIFOS, ACETAMIPRID AND LAMBDA-CYHALOTHRIN APPLIED IN ACIDIC SOLUTIONS

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Codling moth (CM, *Cydia pomonella* (L.) is a key pest of apples and pears in the US. It is common to find a large number of fruit remaining in the trees after harvest. This fruit can become highly infested with CM and give rise to a large overwintering population. The application of ethephon shortly after harvest will result in rapid maturation and drop of unharvested fruit. This suppresses the overwintering CM population. The addition of insecticide to ethephon will kill the adults and hatching CM larvae from eggs that were oviposited on the fruit before the application of ethephon. However, ethephon reduces the pH of the spray solution to 2 to 3, which could affect insecticide performance.
Dose–response bioassays were conducted by treating adult CM with 2 µl/adult of various concentrations of chlorpyrifos, acetamiprid and lambda-cyhalothrin in solutions of pH of 3, 5 and 7. Each insecticide concentration and pH was replicated eight times and there were ten laboratory reared adult males per replicate. Treated adults were then held in a temperature cabinet at 24.5° C with aphotoperiod of 16:8 hr (L:D). Mortality was determined 24 hours after application.

91. LIFE HISTORIES OF CASCADIA BUTTERFLIES

David G. James[1] and David Nunnallee[2]

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For more than a decade, we have pursued, reared, studied and photographed the immature stages of virtually all of the butterfly species occurring from southern Oregon to southern British Columbia, east to Idaho in the region known as Cascadia. The results of this effort will be published in 2010 in a book entitled 'Life Histories of Cascadia Butterflies'. Every species has been reared (often several times) and each stage (egg, all larval instars, pupa, adult) photographed to provide complete image documentation of life histories. In many instances images of eggs, larvae and pupae will be published for the first time. In addition we have compiled data on aspects of the biology and ecology of each species, in many instances providing new information and insights. We also highlight areas for each species in which more research is needed. Such in-depth treatment of the immature stages of butterflies in a faunal region has not been published for any other region in the world. Our presentation will provide a glimpse of some of the images we will publish together with some of the new information on the biology and ecology of Cascadia butterflies.

92. REQUIEM: A NOVEL PLANT EXTRACT – BASED INSECTICIDE FOR PLANT PEST MANAGEMENT

Paul Walgenbach, Kris Rasmussen

AgraQuest, Inc. 1530 Drew Avenue, Davis, CA 95618

Requiem 25EC is a novel plant-extract-base insecticide/miticide. The product was registered by the U. S. EPA in December of 2008. The state registration process is ongoing. Requiem is based on an extract of the essential oil of *Chenopodium ambrosioides,* near *ambrosioides* – a plant closely related to common lambsquarter – whose center of origin is Central America. The refined product contains compounds representing a range of modes of action, the major ones being; disruption of the cuticle, degradation of the tracheal lining and repellency. It has significant activity on soft bodied insects and spider mites. It is safe to many beneficial insects and mites. It is short-lived in the environment and is safe to mammals. This presentation will provide background on the development of the product product and bioassay information confirming its efficacy in various crop-pest complexes.

93. FIELD EFFICACY OF A NEW NORTH AMERICAN METARHIZUM ANISOPLIAE FOR GRASSHOPPERS ON RANGELAND

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USDA ARS, APHIS CPHST and Utah State are evaluating new isolates of Metarhizium anisopliae for Mormon Cricket control. One isolate, DWR346, has emerged as a lead candidate. Topical bioassays by ARS using *Melanoplus sanguinipes* and *Schistocerca americana* revealed that DWR346 had an extremely low LD50 for both insects and a very fast lethality. These data indicated that field control might be possible at rates lower then seen with any other Metarhizium to date.

Adult grasshoppers at population densities (29 grasshoppers per sq m) above the economic threshold were located 7 miles NW of Lusk, Niobrara County WY in mid-June, 2008. A randomized complete block design experiment was designed to include 3 replicate plots each of negative control, a carrier control, and two rates of the DWR346 conidia. The materials were applied by spray equipment mounted on an All Terrain Vehicle at the total volume of 2 gallons per acre to of 0.6 ha plots surrounded by cabaryl–treated barriers to limit migration. Corrected population reductions at 7 and 14d post treatment were: 10% and 24% (carrier control), 34% and 43% ($1.25x10^{12}$ conidia/ha) and 62% and 48% (2.5x1012 conida/ha,) Laboratory bioassays of sprayed vegetation from plots yielded 3%, 75% and 82% *M. sanguinipes* mortality in 10 days. resp.

94. TESTING HABITAT PLANTS AS SOURCES OF ALTERNATIVE APHID PREY FOR SYRPHID FLIES

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A common challenge for biological control is the need to support beneficial insects in a crop system at times when pest densities are low. One strategy for supporting beneficial insects is planting non-crop plants that provide resources such as floral nectar or alternative prey to natural enemies. This strategy is used in organic lettuce fields, where syrphid flies help suppress pest aphids. Growers often use intercroppings of flowering plants to provide nectar to adult syrphid flies. However, flowers provide no food for syrphid larvae. Our research tests the strategy of providing food for syrphid larvae in the form of alternative, non-pest aphids. First, we screened nine habitat plants for their capacity to host non-pest aphids. Second, we examined the adjacent lettuce crop to see whether habitat plants bearing non-pest aphids caused an increase in the abundance of

syrphid larvae and a decrease in the abundance of pest aphids. Results will be discussed in the context of habitat management and resource provisioning.

95. INVASIVE PESTS OF HYBRID POPLAR PLANTATIONS.

John J. Brown[1], Andrew Rodstrom[1], Eugene Hannon[2], Neal Kittelson[3], Douglas Walsh[1]

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Eight years of monitoring pest populations in hybrid poplars grown for saw timber with drip irrigation in eastern Oregon and Washington has provided challenges. Poplars are managed under Forest Stewardship Council pesticide guidelines, so that lumber can be sold with FSC certification. All broad-spectrum insecticides have been prohibited. A successful pheromone strategy was developed against the western clearwing moth (*Paranthrene robiniae*) populations in 2004. Imidacloprid delivered through the drip-line has controlled aphids (*Chaitophorus, Pterocomma,* and *Phylloxerina*) and the cottonwood leaf beetle (*Chrysomela scripta*). Diflubenzuron and indoxacarb have controlled grasshopper (*Cannula* and *Melanohus*) and speckled green fruitworm (*Orthosia hibisci*) problems, respectively. The *Eulophus orgyiae* parasitoid has controlled *Gluphisia septentrionis* and contributed toward controlling *O. hibisci* too.

Two major pests remain, the carpenterworm (*Prionoxystus robiniae*) is a large Cossidae moth that has a biennial life cycle, spending 23 months in larval galleries 36 cm long and 2.5 cm wide in the non-living heartwood. A pheromone based control strategy is proposed against carpenterworm male moths. Secondly, poplar/willow borer (*Cryptorhynchus lapathi*) female weevils and neonate larvae are being targeted with critically timed repeated seasonal applications of imidacloprid.

96. MALE CHOICE IN SEXUALLY CANNIBALISTIC PRAYING MANTIDS: MALES PREFER WELL-FED FEMALES

Michael R. Maxwell[1], Kevin M. Gallego[1]

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Mate choice by males is expected as the costs of reproduction increase for males. In many species of praying mantids, reproduction entails a dramatic cost for males: the risk of cannibalism by the female. Sexual cannibalism occurs in nature for the North American mantid *Stagmomantis limbata.* We examined male choice in this species through a serious of experiments in 2005-2008. In all years, differences in female fecundity were generated through differences in feeding regime -- well-fed females developed many more eggs than poorly-fed females. In captive mating trials in 2007,

males preferred to mount and copulate with well-fed females. In mating trials in 2008, well-fed females did not cannibalize males, while 50% of poorly-fed females did so. Thus, males appear to prefer well-fed females for two reasons: well-fed females are more fecund and less cannibalistic than poorly-fed females. Mate attraction experiments in the field, as well as *in situ* observations of matings in nature, corroborate male preference for well-fed females.

97. PHYLOGENY OF THE CHALCIDIDAE AND THE PROBLEMATIC PLACEMENT OF THE SUBFAMILY DIRHININAE

Andrew Ernst, John Heraty

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Chalcididae (Hymenoptera: Chalcidoidea) are parasitoids of various orders of insects, and therefore potentially useful for biological control. These wasps are relatively large, well-sclerotized and characterized by enlarged hind femora that have multiple and diverse behavioral functions. Five subfamilies are currently recognized within Chalcididae. Previous phylogenetic analyses of Chalcididae were based only on morphology. Molecular analyses do not match the results of the morphology based analyses, and even question the monophyly of the family despite several strong morphological synapomorphies. We are using more comprehensive morphological information, as well as molecular data to develop a more reliable phylogenetic analysis. Dirhininae is a subfamily of Chalcididae that are parasitoids of larval Diptera. These wasps are difficult to place morphologically because they are drastically different from most other subfamilies of Chalcididae. Scanning Electron Microscopy images and other data are used to compile a more complete record of morphological and molecular features that can be applied to determine the placement of Dirhininae within Chalcidoidea.

98. *VOLIAM FLEXI*™: A NEW BROAD SPECTRUM INSECTICIDE FROM SYNGENTA CROP PROTECTION

Christopher Clemens[1] and Caydee Savinelli[2]

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Voliam Flexi™ is a new broad-spectrum, systemic, foliar applied insecticide developed for use for key lepidopteran, sucking and chewing insect pests in vegetables, grapes, pome fruit, stone fruit and potatoes. Voliam Flexi™ received US EPA registration during August, 2008, and is now registered in many tree fruit and potato producing. Field studies in tree fruits conducted during the 2007 and 2008 growing seasons in California, Washington, Oregon, New York, Virginia, North Carolina, and Michigan demonstrated

effective control of key pests such as: peach twig borer, *Anarsia lineatella* (L.), navel orangeworm, *Amyelois transitella* (Walker), oriental fruit moth, *Grapholitha molesta* (Busck), codling moth, *Cydia pomonella* (L.), Spotted tentiform leafminer, *Phyllonorycter blancardella* (Fabr.), pear psylla, *Cacopsylla pyricola* (Foerster), plum curculio, *Conotrachelus nenuphar* (Herbst), Japanese beetle, *Popillia japonica* Newman, potato leafhoppers, *Empoasca fabae*, San Jose scale, *Quadraspidiotus perniciosus* (Comstock), *Hoplocampa testudinea* (Klugs), green fruitworm, *Orthosia hibisci*, tufted apple budworm, *Platynota idaeusalis*, green apple aphid, *Aphis pomi* (De Geer), rosy apple aphid, *Dysaphis plantaginea* (Passerini), green peach aphid, *Myzus persicae* (Sulzer), as well as other insect pests. Voliam Flexi™ is formulated as a 40% water dispersible granule in a 1:1 ratio of thiamethoxam and chlorantraniliprole. Effective use rates range from 112-196 gai/ha for most lepidopteran and sucking pests.

99. THE EVOLUTION OF STREAMER FISHING: FROM ALEXANDRA TO GUMMY MINNOWS

Mark Shelton

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Fly fishing with streamers goes back thousands of years, according to fishing historians. In this country, fur trappers were taught the technique of applying feathers to hooks by native American Indians. British and American fly fishing purists of the 1800s debated whether streamers or bucktails could rightly be called "flies" as they imitated bait fish, rather than insects. When introduced by the British in the mid-1800's, the Alexandra was denounced as too deadly for sport fishing and was actually banned from use in certain European waters. Over time, new streamer styles have evolved, including use of synthetic materials, multiple hooks, tubes, beads, and other items to attract fish to strike. Debate continues today over the use of modern streamers such as the Gummy Minnow in fly fishing. We'll review some of the changes in streamer types over time and discuss their use in freshwater fishing.

100. THE INTELLECTUAL BORDERLAND: WHERE SCIENCE, ART, EDUCATION AND FLY FISHING MEET

Diane E. Ullman

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Inspiration to environmental literacy and a desire to solve the planet's problems must touch the hearts and the minds of children, university undergraduates and community

members. Insects are the most abundant animals on the planet, yet they are facing a dangerous and extraordinary extinction event. As educators, how can we inspire people to appreciate, study, and conserve insects when they are so often reviled and misunderstood? The Art/Science Fusion Program is committed to the concept that teaching and learning are essentially experiences of sharing. There are patterns, harmonies, symbols, and perceptions that are shared across borders and disciplines, where knowledge and wisdom unite and define who we are. We have developed an art/science fusion teaching and learning paradigm that creates accessibility and inclusion for people that would otherwise fear insects, or fear art, and reaches for expression within the classroom that creates value and a shared meaning system. Not only does the paradigm provide a new and innovative classroom learning experience, it creates collaborations between different kinds of students and the community. Perhaps the ultimate in art-science connections, fly fishing offers accessibility to the environment, to the science surrounding fish survival and health and a strong motive to understand and conserve the insect world that is so intimately connected to fish survival and the mystical experience of lifting a rod and casting a line with gossamer thin tippet across the water. Archeologists believe that the fishing hook was first discovered more than 30,000 years ago. Mosaics and literature from the first and second century AD clearly suggest that the art and science of fly fishing was valued as an essential part of daily life. In our contemporary world, fly fishing connects people to the environment, inspires an understanding of the insect world and challenges a generation to a conservation ethic that values clean water and the life it brings. The art/science fusion teaching and learning paradigm flows naturally into the science, Zen and art of fly-fishing giving participants a sense of place and the out of the box thinking needed to bring forward creative solutions to our global problems.

101. THE 'BUGWAN' DEBUGS ENTOMOLOGY FOR THE FLY-FISHER

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De-bugging entomology for the fly fisher is one of the more interesting challenges faced by aquatic entomologists. Fly fishers spend hours tying patterns to match aquatic insects, but often fail to recognize what insects are present and active when they are fishing. And though many fly fishers know dozens of common names for aquatic insects they can be easily confused by their scientific names. The goal of the entomologist then becomes one of simplifying the science while still providing accurate and important information without making the process feel like another biology class they hated in school. This presentation will show an approach to presenting information to fly fishers on insect identification and behavior as it relates to fly pattern selection and fishing tactics. As the Bugwan would say: Keep it simple – Keep it fun – Keep it relevant to fishing.

102. FISH AND MIDGES

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In all stages (larva, pupa and imago) the midges are abundant components of most freshwater systems, where they provide a substantial resource for fish. Larval abundances of near 100,000 individuals m^2 in eutrophic waters in the UK support both coarse (perch) angling and stocked trout fisheries in drinking water reservoirs. The commonest fly lures in these systems are midges. High abundances occur also in more natural systems in the USA, such as the Sacramento River Yolo bypass – a dynamic and productive seasonal floodplain inundated by winter flood diversion. A post-flood initial pulse of invertebrate abundance is dominated by chironomid midge emergence from sediments from which late midge larvae 'revive' from an aestivated condition through summer and fall. Juvenile chinook salmon feed on all stages of the midge and grow faster and fatter when the flooded bypass creates an important feeding area for salmon. In streams, fluxes of terrestrial invertebrates may provide up to half the annual energy budget for drift-feeding fishes such as salmonids, and these fluxes may be dominated by riparian midge imagoes upon which lures may be modelled. Inputs are highest (at least in Australia) from closed-canopy riparian zones that also provide insects such as midges with seasonal flushes of high quality food (fallen leaves, wood), as well as increasing the complexity of microhabitats ('snags') used by fish for refuge and feeding.

103. THE CHALLENGE OF STEELHEAD ON A FLY: UNDERSTANDING BIOLOGY AND DIET

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The enigmatic steelhead is arguably the salmonid most representative of the fishing in western North America. This exciting gamefish has been classified, and misclassified, many times over the years. Once thought to be a unique species, and then placed as a large trout, it is now known to be the anadromous form of *Onchorhynchus mykiss*, the rainbow trout (which is not in the trout genus, *Salmo*, but rather in the genus of Pacific salmon). Whether in the literature or in a river, this fish is difficult to place.

Like other anadromous salmonids, steelhead spawn in the freshwater rivers of the west, although they are different in that they may spawn multiple times. Their ability to make multiple round trips to the ocean makes them remarkable, particularly because they do not feed in freshwater, again, like other anadromous salmonids. Instead, they conserve energy for spawning, often necessary because their natal rivers do not support the biota necessary for feeding such large fish. So, considering that when encountered in western

rivers, they are essentially large rainbow trout that don't feed, how can we attract them to flies? Wet and dry flies that can elicit the striking reflex in steelhead will be discussed.

104. DEVELOPMENT OF ENT 198: ENTOMOLOGY FOR THE FLY-FISHER

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Entomology for the Fly-Fisher at UC Davis capitalizes on the general public's growing fascination with fishing - the most popular participation sport in the US. In 2001, more than 44 million people considered themselves to be fishermen, which is a greater number than the combined number that play golf and tennis. A recent Harris Poll found that fishing was the most popular outdoor activity in the US and was the 4th favorite leisure pastime behind reading, watching TV and spending time with the family. Fly-fishing is a rapidly growing subset of this sport and individuals absorbed into fly-fishing are interested in much more than simply catching fish. On a typical university campus with thousands of students (UC Davis has an enrollment of >31,000), we anticipated that there should be sufficient demand for a course focusing on Entomology for the Fly-Fisher.

This course developed at UC Davis combines aquatic entomology, ecology and fly presentation into an academic course designed with the goal of providing students with a working knowledge of aquatic entomology in the context of fly-fishing. Through laboratories and field collecting trips and student projects we are gradually building a collection for the course. We combine an academic approach with some mechanics and methods and rely heavily on various checklist websites across the country. We intersperse the course with some of the popular fly-fishing literature to keep the course grounded in reality.

The course spans more than just identification, biology, and behavior of aquatic invertebrates and includes allied areas such as salmonid behavior, aquatic ecology (habitat, water quality, etc.), biological diversity and conservation (for both arthropods and salmonids), the impact of dams, endangered species, invasive species, proper catch and release (as well as catch and keep) techniques and PETA's (People for the Ethical Treatment of Animals) objections to fishing. More than 83% of funding for state and wildlife agencies' aquatic resource and management budget is supported by sportsman, so we made the accurate assumption that broader ecological issues would be of interest to students. Through the use of guest lectures, we have tapped the considerable expertise among allied faculty in other departments on campus and they were eager to participate.

105. A NEW LIBERIBACTER SPECIES, CA. LIBERIBACTER PSYLLAUROUS, AND ITS SYMBIOTIC RELATIONSHIP WITH BACTERICERCA COCKERELLI

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A new *Candidatus* Liberibacter species was genetically and ecologically characterized, which infects the psyllid *Bactericerca cockerelli* and its solanaceous host plants potato and tomato (Hansen et al. 2008). Phylogenetic analysis using 16s rRNA, established the new species in the genus *Candidatus* Liberibacter, and the bacterium is designated as "*Candidatus* Liberibacter psyllaurous", an accepted International Committee of Systematic Prokaryotes name, in the first formal description of this new bacterium (Hansen et al 2008). Analysis of *C.* L. psyllaurous's 16s rRNA, intergenic spacer region (ISR), and 23s rRNA gene regions revealed that the same strain of *C.* L. psyllaurous was found in psyllid populations from Texas and California, and in psyllid-*C.* L. psyllaurous infected potato and tomato plants. Based on PCR detection of *C.* L. psyllaurous, bacterial infection frequencies of psyllids are variable between psyllid life stages and the host plants potato and tomato. PCR screening of eggs and egg transfer experiments demonstrated that *C.* L. psyllaurous is vertically and potentially horizontally transmitted. The bacterium was detected at higher infection frequencies in eggs, 1st, and 2nd instar nymphs isolated from potato host plants relative to tomato host plants. In relation to other *Candidatus* species, which cause Huanglongbing (a.k.a. citrus greening disease), transovarial transmission of greening has been found in the psyllid *Trioza erytreae* on sweet orange in South Africa.

In vector-transmission trials all five potato plants and all five tomato plants inoculated with infected psyllids were positive for *C.* L. psyllaurous infection and showed signs of yellowing, whereas control plants were negative for the bacterium and showed no signs of yellowing. Consequently it is highly likely that the symptoms described as psyllid yellows on potato and tomato are caused by this bacterium. All three known citrus Liberibacter species are associated with necrosis of plant phloem tissue and subsequent yellowing of leaves. Necrosis of phloem has also been observed in "psyllid yellow" diseased potato relative to healthy potato plants.

Implications of these finding for disease management on potato and tomato plants are substantial. More information is needed from natural psyllid populations to determine how widespread *C.* Liberibacter psyllaurous infection is in *B. cockerelli*. The host plant range of *C.* Liberibacter psyllaurous, other than tomato and potato, is unknown at this time. Since this insect is polyphagous and has a very wide range of host plants, including many solanaceous plants as well as other families such as pine, spruce, and cedar, other economically and ecologically important plants may be exposed to this disease as well.

Hansen, A. K., Trumble, J.T., Stouthamer, R. and T.D. Paine. 2008. New Huanglongbing (HLB) Candidatus species,"C. Liberibacter psyllaurous", found to infect tomato and potato is vectored by the psyllid Bactericera cockerelli (Sulc). Applied and Environmental Microbiology. 74: 5862–5865.

106. APHID AND VIRUS PROTEINS THAT CONTRIBUTE TO THE REGULATION OF YELLOW DWARF VIRUS TRANSMISSION

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The circulative transmission pathway of luteoviruses through their aphid vectors requires that the virus be actively transported across both gut and salivary tissues as well as survive in the hostile environments of the gut and the hemocoel. This journey is orchestrated by two virus proteins and an unknown number of aphid proteins. The transmission of two related viruses that cause yellow dwarf disease of cereals by *Schizaphis graminum* is controlled by two distinct, but overlapping sets of aphid genes. Aphid genes regulating the transmission of both viruses segregate independently as do genes regulating the transport of virus through gut and salivary tissues. A proteomic analysis of vector and nonvector genotypes has identified numerous aphid and endosymbiont proteins that are involved in cell surface binding, endocytosis, macromolecular transport and trafficking, and immune defense responses. These proteins are correlated with vector and nonvector genotypes or specific tissue types. Several of these proteins have been shown to bind to virus particles. Several proteins have also been shown to be allelic in nature, differing between vector and nonvector genotypes. This is the first system to allow the identification of specific

107. HOW DO MEALYBUGS TRANSMIT GRAPEVINE LEAFROLL-ASSOCIATED VIRUSES?

Rodrigo Almeida

University of California, Berkeley

The development of management strategies to control insect-borne plant diseases is predicated on a solid understanding of pathogen transmission biology. This is specially true for emerging diseases and poorly studied systems, such as grapevine leafroll disease in coastal California. We will discuss research on the biology of Grapevine leafroll-associated viruses transmission by mealybugs to grapevines.

108. INFLUENCE OF TRANSGENIC RESISTANCE TO BARLEY YELLOW DWARF VIRUS IN WHEAT ON THE BIOLOGY OF THE BIRD CHERRY-OAT APHID

Nilsa Bosque-Perez

University of Idaho

Our research addresses ecological and epidemiological relationships among wheat, Barley yellow dwarf luteovirus (BYDV) and the bird cherry-oat aphid, Rhopalosiphum padi, a main BYDV vector. We have studied the biology of R. padi on BYDV-infected or non-infected plants of the virus-susceptible wheat variety Lambert and the moderately-resistant transgenic wheat 103.1J, a Lambert-derived line that expresses the BYDV-PAV coat-protein gene. Virus-infected transgenic plants were inferior hosts for aphids than virus-infected Lambert, while non-infected transgenic plants were superior hosts than non-infected Lambert. Reduced BYDV transmission efficiency after acquisition from virus-infected transgenic plants compared to virus-infected Lambert was observed. Aphids preferentially responded to headspace from virus-infected than non-infected Lambert, but showed no preference for virus-infected compared to non-infected transgenic plants. Aphid responses to virus-infected plants are mediated by volatile cues and are due to attraction rather than arrestment. Volatile organic compounds (VOCs) released by virus-infected Lambert are higher in total concentration and differ in relative component concentrations compared to virus-infected transgenic plants, or non-infected plants of either genotype. Our findings indicate transgenic virus resistance in wheat can indirectly affect vector biology. Such resistance influences production of VOCs by virus-infected plants altering aphid response to transgenic plants relative to non-transformed plants. The combined effects of reduced attraction to, reduced vector population increase on, and reduced virus transmission efficiency after acquisition from BYDV-infected transgenic plants could reduce secondary virus field spread and influence disease epidemiology.

109. SPREAD OF INSECT-VECTORED PLANT PATHOGENS: USE OF SIMULATION MODELS TO ASSESS THE ROLE OF ECOLOGICAL AND OPERATIONAL FACTORS

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The spread of insect-vectored pathogens is dependent on many factors. As a consequence, it is often difficult to predict effects of manipulating one or more factors on pathogen spread. One method to aid in understanding the role of ecological and operational factors on pathogen spread is the use of simulation models. Here the development and use of two stochasitic, spatially-explicit models are reviewed. In the first, effects of insect-vector preference for healthy or infected plants were assessed. This

model suggests that effects of such preference are dependent on assumptions concerning mechanisms of preference and indicate that different outcomes are expected depending on whether healthy or infected plants are preferred. In the second, effects of insecticide applications to reduce vector density and rouging (i.e., removing infected plants) on reducing disease incidence were assessed. Simulation of this model under different assumptions concerning ecology of the vector indicates that management strategies should be tailored to the specific vector targeted for control.

110. USING AERIAL IMAGERY TO IDENTIFY VINEYARDS FOR PIERCE'S DISEASE SAMPLING

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Pierce's disease (PD), a disease of grapes caused by the bacteria, *Xylella fastidiosa* Wells et al., is vectored by the glassy-winged sharpshooter (GWSS), *Homalodisca vitripennis* (Germar). Since 1994, over 1,500 acres of vineyards have been lost to PD in California. Locating infected vines is a critical component behind vineyard-level management strategies. For example, vineyards with high PD incidence would logically require more aggressive vector management than vineyards with little or no PD in the field. This does not mean that growers should relax their vigilance in areas or vineyards with low PD incidence, but by knowing the distribution of PD in their field, growers could prioritize the areas needing the most immediate attention. Also, knowing the location of infected vines is necessary for growers to implement roguing strategies to reduce *X. fastidiosa* inoculum in vineyards.

We are working on a multiple-level sampling program for PD. This presentation will focus on research at the landscape scale, in which we evaluated a sampling method for rapidly identifying vineyards to sample for PD infection. Using aerial imagery to locate large "PD signature areas" we searched approx. 103,236 vineyard acres in Kern and Tulare Counties, identifying 174 vineyards (18798 acres) for sampling in 2007 and 2008; of these, 91 were PD positive. We will discuss the development and future utilization of this sampling protocol within the framework of our overall sampling program

111. EFFECTS OF SINGLE AND MIXED VIRAL INFECTIONS IN THE BIOLOGY OF APHID VECTORS

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University of Idaho[1], University of Georgia[2] and USDA-ARS[3]

Evolution has favored the viruses to evolve with their vectors and hosts in different ways thereby affecting their survival, propagation and transmission. Persistently-transmitted viruses such as PLRV have been known to attract and arrest their vectors compared to non-persistent viruses like PVY. PLRV arrests its vectors longer to encourage sustained feeding, whereas PVY supports shorter feeding periods (probes) by its vector sufficient to successfully transmit the virus. PLRV and PVY infections influence the quality of plants directly affecting the performance of aphids feeding on these plants.

We determined the consequences of single and mixed infections on the insect vectors and how these infections in turn affect the vector dynamics and disease epidemiology. Aphid fecundity was significantly higher on mixed-infected plants than on singly-infected plants or non-infected plants. Both winged and wingless aphids preferentially settled on PVY-PLRV infected plants than on singly-infected plants or non-infected plants. Mixed-viral infected plants with these two heterologous viruses exhibited more severe symptoms than singly-infected plants.

Mixed infections have resulted in synergistic interactions, drastically altering plant viral-susceptibility and physiological status, which severely altered host plant symptom expression patterns as well as vector-preference behavior. Some of these interactions may provide an explanation for the recent spike in incidence of PVY necrotic variants in Idaho and some other regions.

112. CHEMICAL MANAGEMENT OF CUCURBIT YELLOWS STUNT DISORDER VIRUS ON DESERT MELONS

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Cucurbit Yellows Stunt Disorder Virus (CYSDV), a new whitefly-transmitted crininvirus, has recently become established throughout the desert southwest. CYSDV was first reported on melon crops in 2006, and has since increased in severity. Management of the virus has been difficult and expensive, and has focused primarily on whitefly control. Historically, the conservative use of insecticides (imidacloprid at planting; followed by 1-2 foliar applications of synergized pyrethoids and buprofezin)

was the standard approach used by growers to prevent whitefly damage caused by immature feeding and sooty mold contamination. However, because CYSDV is transmitted in a semi-persistent manner by adult whiteflies, this management approach was quickly shown to be ineffective in reducing virus incidence. Since 2007, research has been conducted to evaluate several management tactics aimed at reducing adult transmission including the use of host free periods, row covers, tolerant varieties, and insecticides. Studies have suggested that the incidence of CYSDV can be reduced when adult populations are effectively suppressed with the aggressive use of conventional and novel insecticide active ingredients. This presentation will focus on strategies recently examined for managing whiteflies as a vector, and discuss the long-term sustainability of chemical management of CYSDV on desert melons.

113. RECENT INVADERS ON LANDSCAPE ORNAMENTALS IN SOUTHERN CALIFORNIA

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"Every 60 days, California gains a new and potentially damaging exotic species. The unique and highly varied climate and geography of California presents diverse ecosytems (natural, urban, and agricultural) of which many are perfect for a myriad of new pests to establish and develop damaging populations. California estimates its economic loses to invasive species to be in the hundreds of millions of dollars each year."

The Center for Invasive Species Research, University of California at Riverside

These economic losses are not restricted to crop loss, but also include the costs of quarantine compliance, adverse impacts to the environment from spraying, damage to cars by honeydew, aesthetic costs to urban landscapes, pesticide runoff, and competition with native species.

In the past, California's ocean, mountains, and desert provided natural barriers that kept invasion by exotic and invasive species to a minimum. Because of the dramatic increase in travel, trade and human population, human mediated transport of pests via boats, trains, cars, and trucks have increasingly breached these historical barriers. Exacerbating this situation are budget reductions that have negatively impacted the ability of regulatory agencies to conduct exclusion, detection and eradication programs against exotic and invasive insects.

114. THE IMPACT OF INVASIVE ORGANISMS ON HARDWOODS IN CALIFORNIA URBAN LANDSCAPES WITH EMPHASIS ON THE GOLDSPOTTED OAK BORER

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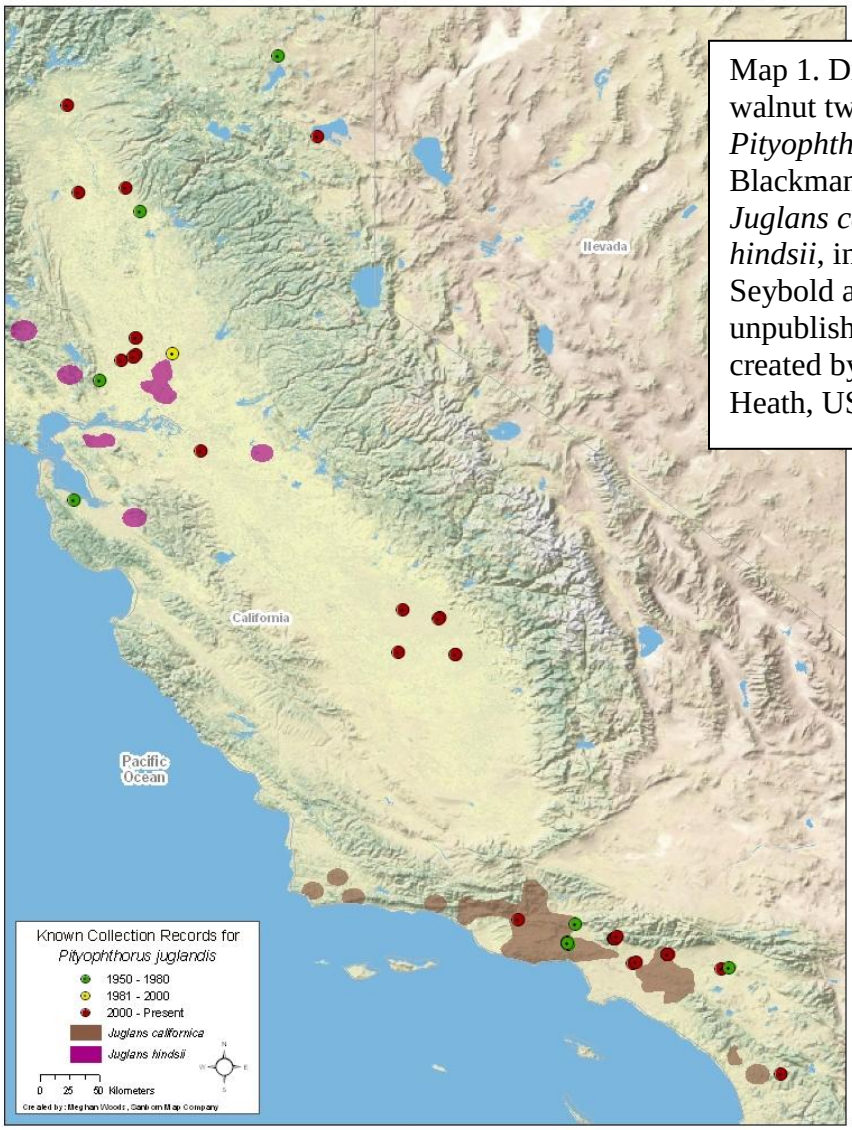
In May 2008, a new and potentially devastating pest of oaks, *Quercus* spp., was discovered in southern California. The goldspotted oak borer, *Agrilus coxalis* Waterhouse (Coleoptera: Buprestidae), colonizes the sapwood surface and phloem of the main stem and larger branches of at least three species of *Quercus* in San Diego Co., California. Larval feeding kills patches and strips of the phloem and cambium resulting in crown die back followed by mortality. Since 2002, aerial surveys in San Diego Co. have detected an estimated 17,000 dead oaks. In a ground survey of forest stand conditions at three sites in this area, 67% of the oaks had external or internal evidence of *A. coxalis* attack. Over 90% of oaks larger than 12 cm in diameter at breast height showed evidence of attack. The zone of infestation appears to be about 50 km (N-S) x 30 km (E-W) and centered on the communities of Descanso and Pine Valley along Highway 8 in southern San Diego Co. Although *A. coxalis* has been collected since the 1880's in Arizona, Guatemala, and Mexico, it was first collected in 2004 within the zone of infestation in California. Prior to 2008, its host association was undescribed. Preliminary observations and trapping surveys with purple- or green-colored plastic sticky panel flight-intercept traps suggest that *A. coxalis* is univoltine in California with adults highly active in flight in late June (and likely earlier). Small numbers of adults continue to fly throughout the summer and fall, with trap captures as late as November. Mature larvae were observed beneath the bark in May and June, and then again in October, and January of the following year, suggesting that the insect overwinters as a mature larva. Full season observations will no doubt reveal the presence of young larvae during the spring and summer. Pupae were collected only from the outer bark, and were observed from mid- to late June, and again in early October.

The impact of another pest of hardwoods, the walnut twig beetle, *Pityophthorus juglandis* Blackman (Coleoptera: Scolytidae), was also recognized in 2008 in California. This beetle vectors an invasive pathogenic fungus, *Geosmithia* sp., and the beetle-fungus complex (called thousand cankers disease) was widely collected in urban and rural plantings of walnuts throughout the state. Infested and infected hosts included the two native walnut species, *Juglans californica* and *J. hindsii*, and to a lesser extent, *J. regia*, which is widely planted for commercial walnut production. *Pityophthorus juglandis* brood galleries on branches (1.5 cm and greater) are frequently associated with staining and initiation of *Geosmithia* canker formation. The beetles carry the fungal spores on their wing covers. Male beetles colonize newly cut branches in 4-9 days and are joined

quickly by 1-2 females and brood galleries are created, often near leaf scars. Both sexes contribute to an aggregation pheromone that attracts both sexes to infested branches. Other insects commonly emerging from dead walnut branches are the lead cable borer, *Scobicia declivis*, a false powderpost beetle, and the oak cordwood borer, *Xylotrechus nauticus*, a roundheaded wood borer.



Map 1. Distributions of walnut twig beetle, *Pityophthorus juglandis* Blackman, and native walnut, *Juglans californica* and *J. hindsii*, in California (S.J. Seybold and colleagues, unpublished data). Map created by M. Woods and Z. Heath, USDA Forest Service.

Although some specialists suggest that *P. juglandis* is an invasive species in much of the western U.S., intensive collecting in 2008 in California and a review of California museum collections have revealed that the beetle is widely distributed in live, dying, and dead walnut branches in the state, ranging from San Diego Co. to Shasta Co. (Map 1). This twig beetle is likely a native associate of *Juglans californica* and *J. hindsii* in the state, but was poorly collected in the past because forest entomologists have tended not to collect insects associated with native walnut. Nonetheless, the native status of the insect in California is supported by numerous cases of old, previously unidentified specimens in museum collections (e.g., 1959-Los Angeles Co., 1973-Riverside Co., 1974-Butte and

Lassen Cos., 1977-San Mateo Co., 1980-Solano Co., and 1982-Sacramento Co.). The 1959 record from Los Angeles Co. and the 1974 record from a remote area of Lassen Co. suggest that the beetle was widely distributed in California long before thousand cankers disease was noted on walnut trees in the state. Thus, *P. juglandis* is likely a native beetle that was poorly collected in the past, but has increased in abundance since it has become associated with an exotic fungal pathogen.

115. INVASIVES IN LANDSCAPES AND URBAN AREAS OF THE PACIFIC NORTHWEST

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Invasive species are gaining ground in the Pacific Northwest at an alarming rate. Of concern is that the regulatory agencies responsible for monitoring exotic species are severely limited in their ability to survey for invasive species due to monetary constraints. Although the efforts of these agencies are diligent, the funding gaps reduce the ability to realistically know the extent of introductions in this region. Monitoring for exotic species is prioritized for detecting key economic pests which have the potential for extensive economic damage in landscapes, forests, and to commodities produced in these states. European and Asian gypsy moths, *Lymantria dispar,* and Japanese beetles, *Popilia japonica,* have dominated survey resources in the Pacific Northwest but careful attention to wood borers has also increased in recent years. Once survey resources are exhausted, detection of exotic invaders becomes more haphazard, reliant on the detection of unusual activity or damage, or by informed professionals or an alert citizenry. This highlights the need for an increased educational focus on such first detectors in these times of reduced budgets.

The rate of new species introduced is increasing according to many of the entomologists involved with detection in the northwest. The Oregon Department of Agriculture noted 22 new arthropod and two exotic gastropod species found from 2007 through 2008. In addition the Oregon State University Insect ID Clinic has documented additional finds. The majority of these new introductions are considered pests of landscapes.

One of the new introductions, walnut twig beetle, *Pityophthorus juglandis* is implicated in the decline of black walnuts, *Juglans nigra,* from the Pacific Northwest to the Rocky Mountains. It is currently thought that the twig beetle vectors the fungus, *Geosmithia* spp., which may cause a potentially lethal disease of black walnuts called thousand cankers disease, also known as black walnut decline. There is no effective management of the disease at this time and many black walnuts have already died or are seriously compromised. Another beetle of concern is the banded elm beetle, *Scolytus schevyrewi*, which was recently found in the Portland metropolitan area in 2007. This beetle was first identified as a new US introduction in 2003 from a Colorado specimen and has since

been found in a number of states, including Oregon and Idaho. The banded elm bark beetle has been found infesting and reproducing in American, English, rock, and Siberian elms but in its native range in Asia has also been found in willows (*Salix*); fruit trees such as apricot, cherry, and peach (*Prunus*); and Russian olives, *Elaeagnus angustifolia*.

There are several new defoliators that have been detected in recent years and making their way south from northern Washington to more populated areas with valuable landscapes at risk. Apple ermine moth, *Yponomeuta malinellus* and cherry ermine moth, *Yponomeuta padellus***;** viburnum leaf beetle, *Pyrrhalta viburni;* dogwood sawfly**,** *Macremphytus tarsatus*; and European pine sawfly**,** *Neodiprion sertifer*, all have dramatic impacts as they continue to expand their territory. Fortunately the introduction of the parasitoid, *Ageniaspis fuscicolis*, for the apple ermine moth, has dramatically reduced damage from both species of ermine moths.

The sesiid borers**:** apple clearwing moth**,** *Synanthedon myopaeformis*; dogwood borer**,** *Synanthedon scitula*; and banded ash clearwing borer**,** *Podosesia syringae,* have been detected in Washington State and have become increasing issues for both native and cultivated host plants in the landscape, nurseries, forest, and fruit tree production. Cherry bark tortrix**,** *Enarmonia formosana,* has devastated many valuable cherry trees and has been detected in Oregon.

Midges: pear leaf midge**,** *Dasineura pyri***;** apple leafcurl midge, *Dasineura mali*; and day lily midge, *Contarinia quinquenotata*; Scale: Lantana scale, *Hemiberlesia lantaniae*; false oleander scale, *Pseudolaulacapsis cockerelli;* Phormium mealybug, *Balnococcus diminutus*; Psylla: Fatsia psyllid, *Cacopsylla fatsiae*; an ash psyllid, *Psyllopsis fraxinicola*; Thrips: heather thrips, *Ceratothrips ericae*; poinsettia thrips; *Echinothrips american* - the list of new species which have become established in the PNW continues to grow.

Reports of new terrestrial mollusk species continue to occur. The vineyard snail, *Cernuella virgata,* was detected in the Tacoma area in 2005 and the longneck slug, *Deroceras panormitanum*, was also confirmed that year in Washington. The wrinkled dune snail, *Candidula intersecta*, was found along the Oregon coast in 2007. The brown lipped snail, *Cepea nemoralis*, and the contracted glass snail, *Vitrea contracta*, were detected in 2008 in Oregon. Idaho has detected brown garden snail, *Cantareus asperses*, in several sites there now.

In most cases, the economic impact of these introductions has not been quantified. One of the few exceptions is the evaluation of the impact from the introduction of the European cranefly, *Tipula paludosa*. This survey estimated home-owner-applied cranefly pesticide treatment costs in Western Washington to be nearly $13 million annually. In the PNW, pesticide use data (one measure of impact) is limited and difficult to obtain, making economic impact of invasive species very challenging to measure. The limited availability of risk assessments prior to introduction, or economic impacts after establishment, hinders the ability to justify funding for much needed surveys and research on eradication and management of these pests.

What does the future hold with reductions in critical invasive species survey, research, and education budgets? How can we stave off the menace of harmful, non-indigenous species? At a time when political leadership is concentrating on stimulating the economy with "shovel ready" projects, politicians should expand their thinking and consider "trap ready" projects that wait funding in nearly every state. This would stimulate local economies, as much of this work still remains labor intensive, employing workers of various skill levels. This would reduce the risk of damage to our landscapes, farms, forests, and waterways. And this would reduce the need to apply pesticides once these pests gain a foothold. There is a wealth of showing prevention is significantly cheaper than the costs associated with eradication and establishment. Funding these endeavors would employ the community and safe-guard our green infrastructure from the many harmful consequences of invasive organisms.

116. RED IMPORTED FIRE ANT: STATUS OF ITS INVASION IN CALIFORNIA

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The red imported fire ant, *Solenopsis invicta*, was detected in almond groves in California's central valley in 1997. Subsequently, in 1998, widespread infestations were found in Orange and Riverside counties in southern California. A statewide eradication program began in 1999, but was terminated in 2003 due to lack of funds. Most of the treatment efforts were centered on North and South Orange Co. and in the Coachella Valley in Riverside Co. Vector control agencies in those 2 regions have continued treatments using funds from property tax assessments. Limited control programs continue in Los Angeles and San Diego counties and the central valley. There are no active treatment programs in West Riverside or San Bernardino counties. All of Orange Co. and parts of the Coachella Valley remain under fire ant quarantine, meaning that all plant nurseries, turf farms, golf courses, and soil movers in those areas are inspected and must treat the fire ants. Fire ants have spread from North Orange Co. into Los Angeles and San Bernardino counties. Most recent new finds are in Chino Hills, Ontario, and as far east as Rialto, where fire ants on a high school football field recently made headlines.

New low toxic baits are now available for fire ants, including indoxacarb and the soon to be available metaflumizone. Combination baits, which contain hydramethylnon and an insect growth regulator, are also in use. In the Coachella Valley fire ant baits can be difficult to use on golf courses due to sprinkler activity. Fipronil granules have been useful for those conditions. Biocontrol of fire ants, using decapitating (phorid) flies and a protozoan (*Thelohania*), are being tried at a few sites to see whether they are viable under California conditions. These parasites are being widely disseminated in the southeastern US.

117. CDFA'S PROGRAMS TO DETECT AND MANAGE INVASIVE INSECTS IN LANDSCAPES AND URBAN AREAS

Kris Godfrey

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The California Department of Food and Agriculture (CDFA) has been active in detection of invasive species since the early 1900's when it became apparent that invasive insects were entering the state through human activities as well as natural movement. Current detection programs are in place for invasive insect pests at the borders, airports, port facilities, production agriculture, natural areas, and urban areas. Detection activities at the borders and ports of entry attempt to find invasive insect pests and deny their entry into the state. Detection activities within the state attempt to find invasive insect pests while they are in early stages of invasion and eradication or management of the pests is possible. For landscape and urban areas, CDFA uses visual inspection, various traps, and education of the public to find invasive insects.

Gypsy moth [*Lymantria dispar* (L.); Lepidoptera: Lymantriidae] and Diaprepes root weevil [*Diaprepes abbreviatus* (L.); Coleoptera: Curculionidae] are examples of two invasive insect pests that mainly invade new areas through man's activities. Detection programs for these two insects include visual inspections and trapping. Detection of either insect in an urban or natural area triggers either an eradication program or a management program. The control tactics used for these programs are discussed.

Asian citrus psyllid [*Diaphorina citri* Kuwayama; Hemiptera: Psyllidae] is an example of an invasive insect that invades new areas naturally and through man's movement of plant materials. Detection and management programs for this insect have just been initiated in California. The impacts of these programs on urban and landscape areas are discussed.

POSTER PRESENTATIONS

1SPO. LABORATORY ANALYSIS AND FIELD SAMPLING OF PNW HONEY BEES FOR THE MICROSPORIDIAN PARASITES, *Nosema apis* AND *Nosema ceranae*

Matthew Smart, Steve Sheppard

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Nosema apis Zander and *Nosema ceranae* are obligate intracellular parasites, classified as microsporidian fungi, that infect the midgut of honey bees. Spores of *Nosema spp.* are believed to be most commonly ingested during the cleaning behaviors of honey bees, at which time bees take up and remove fecal matter, dead and diseased bees, and other foreign or contaminated materials from the hive. The spores are able to build up to extremely high levels in the gut, interfering with the uptake of nutrients, and ultimately decreasing the life span of infected bees.

The survey objective is to identify *N. apis* and *N. ceranae* in Pacific Northwest beekeeping operations. Beekeepers across the PNW send in samples to be tested for the presence of *Nosema spp.* Samples testing positive for *Nosema spp.* spores are then analyzed and identified to species. Additionally, samples from untreated colonies at WSU are collected and analyzed monthly year-round to track *Nosema spp.* presence and prevalence. Spores are counted to estimate mean spore load per bee and DNA is extracted to determine species. The objective of the age cohort study is to track age cohorts of bees as they age and become infected with *Nosema* spp.

2SPO. DETERMINING THE INOCULATION ACCESS PERIOD BY THE POTATO PSYLLID TO EFFECTIVELY INDUCE ZEBRA CHIP POTATO DISEASE

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Zebra Chip (ZC) is an emerging and damaging potato disease that annually causes millions of dollars in losses to the potato industry in the U.S., Mexico, Central America, and New Zealand. ZC symptoms are characterized by a necrotic striped pattern in potato tubers that becomes more pronounced after frying. Recent studies have associated ZC with a new species of *Candidatus* Liberibacter vectored by the potato psyllid, *Bactericera cockerelli* (Sulc). Understanding the epidemiology of this disease and the biology of its insect vector will enable growers to more effectively develop management strategies that

can mitigate losses due to this disease. To determine the disease inoculation access period by the potato psyllid, we examined the length of exposure of healthy potato plants to Liberibacter-infected potato psyllids to effectively induce ZC. Our previous field studies conducted in Wapato, WA in the summer of 2008 indicated that inoculation access period as short as 1 day was sufficient to induce 100% ZC infection in potato tubers. To corroborate and further refine the field data, inoculation studies were conducted under controlled laboratory conditions with inoculation access periods of 7, 5, 3 and 2 days and 24, 20, 16, 8, 4 and 1 hours. Results indicated that inoculation access period as short as 4 hours was effective in inducing typical ZC symptoms.

3SPO. FEEDING PREFERENCES OF THE FIREBRAT AND IMPLICATIONS FOR PEST CONTROL

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For the last one hundred years the firebrat, *Thermobia domestica* (Packard), has been a common pest of economic importance infesting libraries, museums, and pantries all over the United States. Bait stations have had no success in controlling this pest. Firebrats have a very general diet including protein, starch, paper, and cloth. Despite this diet firebrats do not consume the baits in commercial bait stations. In order to create an effective bait for control of these insects a bait base must be used that will be readily consumed.

I am studying the dietary preferences and requirements of firebrats. My goal was to identify the qualities of an ideal bait base, and understand why existing baits may or may not be consumed. Foods were compared using a series of choice tests in order to determine which foods are preferentially attacked. I have observed that solids and powders are strongly preferred to gels and liquids. A starch based food may not be preferred over a protein based food. However firebrat feeding on dry foods is strongly influenced by certain qualities of the food, including physical qualities and composition of ingredients.

4SPO. VIBRATIONAL MATING CALLS OF BLUE-GREEN SHARPSHOOTERS (*GRAPHOCEPHALA ATROPUNCTATA*) AS INDICATION OF INCIPIENT SPECIATION BETWEEN POPULATIONS IN CALIFORNIA

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Native blue-green sharpshooters (*Graphocephala atropunctata*) are widely distributed across California with a range that encompasses more than 700 miles. Although populations from northern and southern California exhibit strong morphological differences, they are considered to be the same species. This study sought to examine differences between populations in an effort to determine if *G. atropunctata* is actually a species complex. Vibrational mating calls are used extensively by *G. atropunctata* and therefore play an important role in mate selection and breeding. Differences in these mating calls between northern and southern California (populations separated by 560 miles) were examined by recording groups of virgin individuals for 24 hours that were calling for mates. The types and frequencies of these calls were compared between the two populations and significant differences were found in both call type and number of calls. To further examine differences between these two populations, cross breeding studies were employed to examine the frequency of offspring production between these two populations. Cross breeding results suggest that *Graphocephala atropunctata* strongly prefer to mate with individuals from their own population. Differences in both mating calls and cross breeding preferences are strong evidence supporting incipient speciation of blue-green sharpshooters across California.

5SPO. IMPACT ASSESSMENT OF VINEYARD FUNGICIDES ON THE PREDATORY MITE *TYPHLODROMUS PYRI*

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Fungicide programs in western Oregon vineyards are believed to contribute to secondary pest outbreaks of the rust mite *Calepitrimerus vitis* (Nalepa). Laboratory bioassays are currently being conducted to assess the effects of commonly applied vineyard fungicides on *Typhlodromus pyri* Scheuten (Acari:Phytoseiidae), a key predator mite of *C. vitis*. Six vineyard fungicides (Cosavet™ sulfur, Tillamook® whey powder, Manzate®, Pristine®, Rally™ and JMS Stylet-oil®) are being tested at three levels of concentration (recommended label rate (LR), 0.5x LR increase and 1.0x LR increase) on juvenile and adult *T. pyri*. Appropriate fungicide dilutions are directly sprayed onto juvenile or adult *T. pyri* with a Precision Potter Tower. The effects of each treatment are assessed at specified days after treatment (DAT) in order to determine mite mortality, fecundity and oviposition rate. Results reported here are preliminary and include three fungicide treatments at the LR concentration. Initial 7 DAT results indicate less than 50% lethal effect on adult and juveniles, respectively using sulfur (19%, 2%), whey powder (11%, 1%) and Pristine® (6%, 9%). Mean reproduction rate is also similar across treatments with 4.04 (sulfur), 4.34 (whey powder), 4.25 (Pristine), 5.13 (water) and 5.21 (no spray) eggs oviposited per female over 7 days.

6SPO. CUTTING FAILURE AND DAMAGE CHARACTERIZATION IN PACIFIC NORTHWEST HYBRID POPLARS

R. Andrew Rodstrom, John J. Brown, John R. Rodstrom and Martin E. Fortney

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Hybrid poplars grown in the inland Pacific Northwest are an irrigated woody crop grown to meet today's fiber demands. Harvest generally occurs during winter when most pests are dormant. In spring, growers replant the recently harvested areas with cuttings. Due to the small leaf area, fragile roots and limited reserves, cuttings are vulnerable to several common above and below ground pests during this first growing season. As these cuttings represent a long-term investment, it is imperative for the grower to know which pests are causing economic injury and where it is occurring.

Cutting mortality within planting units was recorded, characterized and then mapped using Spatial Analysis and Decision Assistance (SADA). These techniques allow the recognition of species-specific mortality patterns unique to each planting unit. Although the location of cutting mortality within units is not consistent, mortality patterns can be linked to individual pests. These patterns of mortality seemed to be linked to the pest's mobility, with highly mobile pest showing a broad distribution and sessile pests causing localized pockets of mortality. Although we have not been able to predict where insect-caused mortalities will occur within a planting block, we have identified the major pests and both their characteristic damage and mortality patterns using SADA.

7SPO. THE POLLEN FORAGING BEHAVIOR OF A NATIVE POLLINATOR, *BOMBUS VOSNESENSKII* (HYMENOPTERA: APIDAE), IN AN AGROECOSYSTEM

Kimberly M. Skyrm, Sujaya Rao, William P. Stephen

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While the western honey bee, *Apis mellifera*, has traditionally provided pollination services for a diversity of crops, parasites and diseases have reduced their availability and increased their cost. As a result, growers have turned to native bee pollinators as an alternative pollination resource but information on their abundance and foraging efficiencies is limited.

The foraging behavior of a dominant bumble bee species, *Bombus vosnesenskii*, was evaluated in red clover seed production fields in western Oregon, where producers typically utilize honey bees for pollination. The study addressed the following: 1) Do native bumble bees and managed honey bees exhibit similar pollen foraging behaviors?

2) Does the foraging behavior of native bumble bees vary with colony size or changing floral resources?

To compare foraging behavior, counts of bee foragers were taken during two-minute visual observations through red clover bloom. The results indicate temporal differences in pollen foraging as a larger proportion of bumble bees were observed carrying pollen during late season when compared to honey bees ($p = 0.03$). In evaluating colony level foraging behavior, individual bumble bee workers from large and small colonies were marked and observed during peak foraging periods. Trends in foraging behavior and floral preferences will be presented.

8SPO. DISPARATE REPRODUCTIVE STRATEGIES OF LEAFROLLER-ATTACKING TACHINIDAE IN WASHINGTON ORCHARDS

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The tachinid flies *Nemorilla pyste* (Walker), and *Nilea erecta* (Coquillet) rank as the most abundant parasitoids of obliquebanded (*Choristoneura rosaceana* Harris) and *Pandemis* (*P. pyrusana* Kearfott) leafrollers (Lepidoptera: Tortricidae) in central Washington apple orchards. Although multiple rearing records of these parasitoids exist, before the current study, most biological knowledge of these species was inferential from relatives within their respective tribes, Winthemiini and Eryciini. We have successfully brought both of these tachinid species into culture to study their biology and provide a foundation for improving biological control. Here we report on important differences in reproductive strategy between these parasitoids. These results were obtained through observation of parasitoid attack behavior, quantification of fecundity, and dissections of adult female flies to determine reproductive morphology and ovigeny. The disparate reproductive strategies of these parasitoids are discussed in terms of the rate at which eggs are produced, incubation, fecundity, and the relative costs and benefits of each strategy. Also discussed are the accuracy of phylogenetic predictions regarding fecundity and mode of attack of these species.

9SPO. EFFECTS OF ALLOCHTHONOUS ORGANIC MATERIAL ON LARVAL MOSQUITOES (DIPTERA: CULICIDAE)

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Terrestrial inputs of leaf litter provide the base of much of the food web in freshwater ecosystems. Biofilms that develop on the leaf litter are the major food source for aquatic

invertebrates. Although upland trees often border seasonal wetlands, their leaves have been shown to be poor providers of nutrients necessary to the development and maintenance of biofilms, leading to poor insect development. Previous studies have shown that eucalyptus extracts can be used to control *Aedes aegypti*, potentially adding a new phytochemical to the integrated mosquito management arsenal, though its broad applicability is untested.

This study examined the ability of three mosquito species (*Ae. aegypti*, *Culex quinquefasciatus*, and *Cx. tarsalis*) to develop in water containing eucalyptus leaves and bark. One hundred second-instars were placed into 750 mL of distilled water that was supplemented with either 7.5 g of dried eucalyptus leaves, 7.5 g of dried eucalyptus bark, or mouse chow added *ad libitum*. Virtually no adults emerged from treatments containing eucalyptus bark. *Cx. tarsalis* did not survive in treatments containing eucalyptus leaves. Adult mass of *Ae. aegypti* reared in water with eucalyptus leaves did not differ significantly from that of individuals reared in water with the mouse chow laboratory diet.

10SPO. EFFECTS OF ADJACENT LAND USE ON BENTHIC MACRO-INVERTEBRATES IN THE UMATILLA RIVER, EASTERN OREGON

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The Umatilla River drains a watershed dominated by agriculture in eastern Oregon, and alterations have been made in the river channel and on the adjacent land. In this study, macro-invertebrates were collected from three different riverine habitat types along the river: “test” sites heavily impacted by agriculture, “reference” sites that were relatively un-affected by agriculture, and “restoration” sites that were designed to buffer the river from agricultural impacts. Taxonomic communities were compared among these habitat types to determine the impacts of land use on the benthic aquatic assemblage. It was expected that test sites would represent a different abundance and diversity of macro-invertebrates than reference sites, and that restoration sites would be more similar to reference sites. Analysis of data showed that there reference sites exhibit greater diversity and abundance for taxa sensitive to disturbance, and test sites showed greater abundance of taxa tolerant to disturbance. However, restoration sites were represented by macro-invertebrate communities that differed from both test and easement sites. Greater understanding of the effects of land management and restoration techniques on aquatic biota, with long-term bio-monitoring of management regimes, is necessary for the protection of freshwater systems.

11SPO. ORNATE ANT-KILLERS CONQUER AFRICA

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Kapala (Hymenoptera: Eucharitidae) are parasitoids of poneromorph ants. They are found mainly in the New World, and are comprised of 19 described species and possibly as many as 60 undescribed species. Only one species is known to occur outside of the New World, with *K. ivorensis* widespread across the tropical Ethiopian and Malagasy regions. Neotropical *Kapala* are commonly collected and extremely diverse morphologically. In contrast, *K. ivorensis* has little morphological variation and few specimens are found in research collections. Based on previous research, the Old World distribution is believed to be the result of a recent divergence event. Molecular evidence from a combined-gene dataset (28S D2-D3, 18S, COI, COII, and ITS2) is used to assess the divergence of geographically disjunct African populations and identify possible sister species from the New World. This data supplements a comprehensive collection of digital images captured to document and compare morphological variation within and between species. The assessment of species boundaries in *K. ivorensis* and potential biogeographic scenarios will be discussed.

12PO. A NEW MICROBIAL INSECTICIDE FROM *CHROMOBACTERIUM SUBTSUGAE*

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Marrone Organic Innovations has licensed a technology based on a novel species of *Chromobacterium* from USDA and is developing it into a microbial bioinsecticide. The development work includes media optimization to maximize the yield of secondary metabolites responsible for insecticidal activity as well as formulation development for increased efficacy and storage stability. Bioactive compounds are extracted from fermentation broths and the resulting crude extracts are fractionated for compound isolation and identification. Our studies confirm the previous data from USDA; the insecticidal activity of fermentation broths develops over time and coincides with the cell death during the stationary growth phase. Cell-free extracts have good activity against insect pests. The active compounds in the whole-cell broth seem to be heat-stable but some activity is lost during freeze drying. Work is in progress for media optimization, formulation development and active compound identification. Spectrum testing against various insect pests is continuing through bioassays as well as greenhouse and field studies.

13PO. EYE DEVELOPMENT IN THE TERMITE INCISITERMES MINOR - MORPHOLOGY AND ELECTROPHYSIOLOGY

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As other dry-wood termites, *Incisitermes minor* has a linear developmental pathway, comprising six larval stages and two nymphal-instar stages. Typically pigmentation of the eyes occurs during the late second nymphal-instar stage, suggesting functional eyes only in individuals just before becoming an alate (Katoh H et. al. 2007 Insect Sociaux 54).

In *I. minor* pigmented eye cells occur already in the third larval stage. Then the number of pigmented cells increases with each step of development. To investigate functionality we recorded electroantennograms (ERGS) from termites of stages L6, N1, and N2. The ERGs obtained from all individuals are similar to ERGs of other hemimetabolous insects. 1 second stimulation (high intensities, white light) led to responses with phasic and tonic components. Short stimulations (between 1/500s and 1/30s) with high intensities always led to phasic responses. Low light intensities of white light (neutral grey filters) led to tonic responses. Responses to red light are ~40% compared to responses to blue or green light. Pigmentation, electrophysiological results, and preliminary behavioral tests suggest that *I. minor* has functional eyes already at developmental stages that remain constantly in the darkness of their nests.

14PO. LYGUS BUG RESURGENCE FOLLOWING PYRETHROID TREATMENTS TO ALFALFA GROWN FOR SEED

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Two insecticide studies for lygus bug control were conducted at the University of California Desert Research and Extension Center during the 2007 and 2008 alfalfa seed production seasons.

Insecticidal treatments included experimental chemistries, new unregistered compounds, newly registered insecticides, older registered insecticides, and combinations of chemistries as tank mixtures or in-the-can mixtures. All insecticide treatments were efficacious for lygus bug control initially, including treatments with pyrethroid insecticides. Later in the production season, treatments with pyrethroid insecticides used alone or in combination with other classes of chemistries showed a resurgence of lygus bugs that occasionally exceeded the levels in the untreated control plots. The cause of the lygus bug resurgence following pyrethroid insecticide treatments has not been

determined. Because lygus bugs were initially susceptible to pyrethroid insecticide treatment but later populations increased to levels that equaled or exceeded the untreated control, the pyretriod chemistries may be causing hormoligosis, abnormally high reproductivity. Another possibility is the release of lygus bugs from natural enemies. Both of these possible causes of lygus bug resurgence, as well as other possible causes such as pesticide resistance, need to be investigated.

15PO. RICE WATER WEEVIL SAMPLING FOR COMMERCIAL MONITORING – POSSIBILITIES AND CHALLENGES

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The rice water weevil is the most important insect pest of rice in the Sacramento valley. Populations vary considerably with year and location. Because of the irregularity of infestations, preventive insecticide applications are not always appropriate. Curative insecticide applications should be based on field population levels. However, current rice water weevil monitoring methods are difficult and time consuming.

Given the aquatic habits of adult rice water weevils in rice fields, the use of an aquatic net may constitute an easy-to-use and cost-reliable monitoring method. Early during the 2008 season aquatic net and soil core samples were taken in two commercial rice fields and the average number of larvae per core per check regressed against the average number of adults captured with the aquatic net. Results show that it may be possible to predict larval populations based on the number of adults caught with the aquatic net or the proportion of aquatic net samples that caught adults.

16PO. CROP CULTURAL MANAGEMENT OF ONION THRIPS AND IRIS YELLOW SPOT VIRUS

Diane Alston, Jennifer Reeve, Daniel Drost, and C. Kent Evans

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Onion thrips and Iris yellow spot virus (IYSV) threaten sustainable, profitable onion production in Utah and the Western US. Onion thrips is the primary vector of ISYV. Onion growers in Utah rely on high-risk insecticides for thrips management, which has increased insecticide resistance and may increase the severity of IYSV outbreaks. Very little is known about how to effectively manage IYSV. We do not know if cultural practices affect its spread and whether more intensive thrips insecticide programs reduce IYSV incidence or severity. In 2008, we surveyed 15 onion fields in northern Utah to ascertain the effectiveness of IYSV and thrips management strategies used on commercial onion farms. We determined the incidence of thrips, IYSV pressure, and key

timing of pest outbreaks, and if these were correlated to commonly used farm practices such as fertility, herbicides, insecticides, fungicides, irrigation, and crop rotation.

17PO. CHARACTERIZATION OF MICROENCAPSULATED PEAR ESTER SPRAY ADJUVANT, AND BEHAVIOR EVOKED IN CODLING MOTH NEONATE LARVAE

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A microencapsulated formulation of codling moth (CM), *Cydia pomonella*, larval-attractant kairomone, ethyl (2*E*,4*Z*)-2,4-decadienoate, the "pear ester" (DA-MEC; Cidetrak, Trece Inc.), enhances control efficacy of various insecticides when tank-mixed as a spray-adjuvant. DA-MEC formulation is characterized, including microcapsule size, concentrations, emission rate, and laboratory dual-choice pedestrian bioassays on neonate CM larvae. Diameter size of the thin-walled microcapsules ranged from 2 to 14+ μm, with 68.6% of capsules being 2–3 μm. At the field application dilution of DA-MEC formulation the concentration of microcapsules averaged 264.6 x 10^3 capsules per mL spray solution. SPME headspace collections and GC-MS analysis showed the evaporative emission of pear ester over 21 days followed power and exponential trendline decay curves. Extrapolations of the trendlines suggest picogram emissions of pear ester would extend to 2.5 – 3 weeks. Newly hatched CM larvae spent significantly more time (64.0 $\pm$ 0.7%) crawling within filter paper zones treated with dilute field rate DA-MEC than untreated zones for up to 14 days during evaporative aging. Observed strong orientation preferences, extended crawling time, and frequent arrestment stopping by CM larvae support that PE kairomone evokes increases in "larval wandering." Applications of DA-MEC spray adjuvant with insecticides may evoke an increase in neonate wandering upon foliage, thereby disrupting host fruit/nut finding, as well as enhancing mortality by increasing the exposure to insecticides.

18PO. IDENTIFICATION OF NATURAL ATTRACTANTS OF GUAVA WEEVIL IN AGUASCALIENTES, MEXICO

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Guava weevil, *Conotrachelus dimidiatus* (Champion), is one of the most important guava pests in Mexico. The damage occurs by female oviposition in the middle part of green fruits affecting the production and commercialization of guava fruits. Pest management relies on chemical control using products such as Malathion and Parathion methyl. Because the natural impact of chemical products and the economic importance of the guava in Aguascalientes, Mexico was implemented a new ecological strategy for pest control. Based on chemical ecology principles, isolation of volatiles compounds were made from males, females and guava fruits using SPME and dynamic headspace aeration techniques. After that, microinjections of isolates were made in gas chromatography-mass spectrometry (GC-MS) for their identification. Our results indicate the existence of "green volatiles" on guava fruit as pinene, limonene, and caryophyllene. Besides compounds related with adult weevils such as 3 – hexen – 1 –ol, 1 – hexanol – 2 ethyl and tetradecane. Preliminary results in field using pyramid traps with combination of these compounds showed that double and triple combinations were effective to attract guava weevil adults with at average of 1.18. ± 0.18 adults per trap.

19PO. EVALUATION OF SYNTHETIC FEMALE-PRODUCED SEX PHEROMONE OF PRIONUS CALIFORNICUS (CERAMBYCIDAE: PRIONINAE)

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Prionus californicus Mots. (Cerambycidae: Prioninae) is broadly distributed in western North America. Adults are crepuscular, active during summer and early fall and are among the largest cerambycids in North America, ranging in body length from 2.5 to 4.5 cm. The adult females oviposit in soil near the bases of living woody plants and the larvae feed on roots, requiring 3-5 years to complete development. The larvae are a serious pest of hop, *Humulus lupulus* L. (Urticales: Cannabaceae), in the northwestern United States, and because of their subterranean habit are very difficult to manage. Options for management are limited to rouging infested plants, or removing all plants in heavily infested fields. Males are strongly attracted to a volatile pheromone produced by female *P. californicus* that might prove useful for managing this beetle in hop. We have recently identified the pheromone as an isomer of 3,5-dimethyldodecanoic acid. In this

work we report the results of laboratory and field studies identifying the active enantiomer and characterizing the activity of the pheromone.

20PO. FIELD–CAGE EVAULATION OF TWO INTRODUCED OLIVE FRUIT FLY PARASITOIDS IN CALIFORNIA

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The olive fruit fly, *Bactrocera oleae* (Rossi) (Diptera: Tephritidae), invaded California around 1998 and has become a major olive pest in all olive growing areas in California. A classical biological program was initiated in 2002, and two larval fruit fly parasitoids, *Psyttalia lounsburyi* (Silvestri) and *P. concolor* (Szépligeti) (all Hymenoptera: Braconidae), have been introduced from Africa into California and permitted for field release for the control of the olive fruit fly. We evaluated the effectiveness of those two parasitoids through field-cage tests in the San Joaquin Valley of California. Twenty-five field-cage testes were conducted in different olive growing seasons during 2006-2008. Parasitism by *P. lounsburyi* ranged from 8.6 to 28.1%, which was overall lower than that by *P. concolor* (ranged from 20.5 to 80.0%). In both species, parasitism of larval olive fruit flies was higher in smaller fruit cultivar 'Manzanilla' than in larger fruit cultivar 'Ascolana'. The highest parasitism by each species was observed in October. Data suggest that seasonal temperature extremes in summer and fall reduced the levels of parasitism.

21PO. CONTROL OF THE INVASIVE THRIPS, *KLAMBOTHRIPS MYOPORI*, ON LANDSCAPE PLANTINGS OF *MYOPORUM* IN CALIFORNIA

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Klambothrips myopori Mound and Morris is a relatively recent introduction into the U.S. and has severely impacted landscape plantings of *Myoporum* (Myoporaceae) along the caost from San Diego County to Marin County. *Myoporum laetum* G. Forst. is a popular tree and ground cover in coastal California that is widely planted because of its aesthetic beauty, minimal management needs, and low water requirement. Infestations of *K.*

myopori have been severe enough to kill landscape plantings of myoporum trees and severely stunt myoporum ground cover. Leaves are twisted, folded and stunted forming a protected area for *K. myopori* to feed and reproduce. Stunting is so severe that it causes complete necrosis of terminals with little or no regrowth. We have conducted several insecticide trials using the highest recommended rates of a variety of neonicotinoids as foliar applications on mature myoporum plantings and evaluated their effects on thrips populations as well as monitoring for plant recovery rates. Two products provided very good control and excellent recovery of leaf tissues and terminal growth. Imidacloprid plus bifenthrin (Allectus, Bayer) and thiamethoxam (Meridian, Syngenta) performed best. In addition, we have observed and will discuss the presence of an opportunistic native predator, *Orius tristicolor* (White), feeding on the thrips in most of our samples.

22PO. UNDERSTANDING THE DYNAMICS OF NEONICOTINOID ACTIVITY IN THE MANAGEMENT OF *BEMISIA TABACI* WHITEFLIES ON POINSETTIAS

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In this study, we monitored the development of whitefly populations, *Bemisia tabaci* (Gennadius), on poinsettias, *Euphorbia pulcherrima* Willd. ex Klotzsch, treated with either foliar or soil drench (systemic) applications of two neonicotinoid insecticides, imidacloprid and dinotefuran. We evaluated the top recommended label rates for systemic imidacloprid (10.6 mgs/15-cm pot) and foliar treatments of both imidacloprid (27.3 mgs/liter applied to complete wetness) and dinotefuran (120 mgs/liter). We evaluated the lower recommended rate for systemic dinotefuran (21.6 mgs/15-cm pot). We used ELISA and LC/MS to quantify the residues of these insecticides in leaves sampled from the treated plants, which allowed us to relate insect survivorship and population development with the levels of insecticide that were present on (foliar) or within (drench) the plants. The drench application of dinotefuran was the only treatment that remained effective at suppressing adult whitefly numbers below pre-treatment levels throughout the 10-week assessment period. On plants treated with foliar dinotefuran, and both foliar and systemic imidacloprid, there was a steady recovery of adult and nymph populations, beginning at the emergence of the F1 generation. The ELISA data derived from this study suggest that the target thresholds for systemic imidacloprid are above 37 ng/cm^2 leaf (based upon the average titers at weeks 1, 2, and 4 after treatments). Concentrations of systemic dinotefuran at 240 ng/cm^2 prevented the establishment of whiteflies, although lower concentrations may be equally effective.

23PO. TRANSITION FROM SMALL SCALE REARING TO MASS PRODUCTION OF LIGHT BROWN APPLE MOTH (EPYPHYAS POSTVITTANA) FOR SIT

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Challenges in transition from laboratory size culture to large scale operation producing millions of insects involves developing technology that will produce high quality insects at a reasonable cost. We present experimental work that was performed in order to develop a technique to increase production and maintain consistent good quality of insects. Capacity of insects to produce continuously large production of eggs is essential for expanded production and important parameter for quality control. Fecundity and hatch of light brown apple moth was studied from the aspect of diet, ovipostional substrates and pupal handling. Fecundity and egg hatch was assessed in LBAM provided with 10% sucrose solution, water and no food or water source. Different non-natural substrates including transparent polypropylene and brown butcher paper were compared for ovipositional preference, egg hatch and convenience of handling. Implementation of rearing techniques based on obtained results is discussed.

24PO. IPM PROGRAMS IN TREE FRUIT: FROM LARGE-SCALE COMMERCIAL ORCHARDS TO SMALL-SCALE HOME ORCHARDS

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Alternatives to organophosphate insecticides have been implemented on a large proportion of the commercial pear acreage in southern Oregon. The use of puffers for dispensing pheromones for mating disruption of codling moth, *Cydia pomonella*, has increased markedly over the last four years. Codling moth has been managed effectively in commercial pear orchards using organically certified control methods such as mating disruption supplemented by codling moth granulosis virus. Due to the fact that extra-orchard sources of codling moth can pose a threat to IPM and organic programs, a multi-tactic approach utilizing only biological and behavioral methods for controlling codling moth was designed for small-scale and home orchards. This program which uses applications of the codling moth granulosis virus, entomopathogenic nematodes, *Steinernema carpocapsae*, and trapping for female codling moth was evaluated in 2008. A high level of codling moth control was achieved in the treated sites, in the check sites the number of successful codling moth entries in apples averaged 0.58 per fruit while in those sites which received the full combination of treatment methods the number of

successful entries averaged 0.03 per fruit. Better codling moth control was associated with greater site isolation and a higher degree of horticultural management.

25PO. STEM-SEGMENT DEVELOPMENT OF SCHLUMBERGERA AND HATIORA SPP. WHEN EXPOSED TO THE WESTERN FLOWER THRIPS

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Stem segment development of Christmas cactus, *Schlumbergera bridgesii*, and Easter cactus, *Hatiora gaertneri* (formerly *Rhipsalidopsis gaertneri*), is severely stunted due to the presence of the western flower thrips. Thrips feeding on terminal buds causes abortion of the buds and a concomitant reduction in the number of stem segment terminals. Five cultivars were selected to be isolated in cages with or without thrips and stem length development was followed. The average number of stem segment buds was significantly greater for all cultivars not exposed to thrips in cage studies. An efficacy trial was conducted to determine the how well selected pesticides would protect *Schlumbergera* (cv. 'Thor-Ritt') grown on benches in an open shadehouse from reduced stem segment development due to the thrips. The neonicotinoids Imidacloprid and thiamethoxam, the pyrethroid labda-cyhalothrin, the spinosyn spinosad, and the organophosphate acephate were used in the trial. All treatments caused significantly greater stem segment development compared to the control.

26PO. DOES CONTROLLING BEET LEAFHOPPER IMPACT THE ENDANGERED BLUNT-NOSED LEOPARD LIZARD (*GAMBELIA SILA)?*

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Beet curly top virus is a debilitating plant pathogen to several important agricultural crops of California. The sugar beet leafhopper, *Circulifer tenellus* (Baker) (Homoptera: Cicadellidae), is the only known vector of this phytopathogen. Crop damage by beet curly top virus is traditionally controlled by (1) cultural practices that seek to remove host plants of the insect vector within and near susceptible agricultural crops, (2) the use of pathogen resistant plants, and (3) direct management and control of the insect vector. Direct management and control of this insect typically involves treating non-agricultural native habitat into which the insect migrates during the late fall and winter seasons. Treatment of natural areas for vector control is typically done through the aerial application of malathion at a rate of 0.264 Kg per acre of active ingredient. Recently, concerns involving the treatment of non-agricultural, natural, areas for sugar beet

leafhopper control have emerged due to potential effects of insecticide treatments on the food resource base of the endangered blunt-nosed leopard lizard, *Gambelia silus.* The diet of this lizard species is composed primarily of insects, and small arthropods. The impacts of aerial malathion treatments upon arthropod communities within *G. silus* habitat or upon the food resource base of *G. silus* are unknown. The objective of this study was to determine the impact of low-impact malathion treatments on arthropod communities (diversity of species, number of species) within *G. silus* habitat. Our results indicate that the overall impact of aerial treatment of malathion on arthropod abundance was minimal. Variation in abundance due to annual, seasonal, and spatial factors was far greater than any variation due to insecticidal treatment using this method of application. Although there were seasonal and annual changes in arthropod community structure and species richness between and within years, this impact was not consistent across all years of the study. For ground dwelling arthropods, a significant negative impact on community structure and species richness with treatment was only evident in the terminal year of the study. For aerial flying insects, treatments negatively impacted community structure with a reduction in species richness in two out of the three years examined. As the blunt-nosed leopard lizard is an opportunistic and generalist predator, we believe our data demonstrate that minimal impact on the food resource base of blunt-nosed leopard lizard will occur with these type of treatments. Although there may be significant changes in species richness and community structure with treatment, there is little impact on overall abundance of potential "food" (=abundance) for the lizard.

27PO. HAZELNUT CULTIVAR SUSCEPTIBILITY TO FILBERTWORM AND SEASONAL NUT INFESTATION PATTERN IN OREGON

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The filbertworm, *Cydia latiferreana* (Walsingham), is a key pest of hazelnuts in Oregon. Information on the biology of filbertworm is still incomplete, hindering the development and implementation of alternative and effective control measures. To determine the susceptibility of hazelnut cultivars to filbertworm, nut samples were taken from 18 unsprayed cultivars in 2008. Infestation rate and shell thickness were examined. In addition, the timing of nut infestation was studied in an abandoned orchard by enclosing nut-bearing hazelnut branches. These branches were sequentially exposed to filbertworm for two week intervals from May to October 2008. Results show that infestation in the different cultivars ranged between 2 and 73%. Percent infestation was negatively correlated with shell thickness at the basal scar, but not at the side of the nut. Nut infestation in the abandoned orchard occurred from beginning of June until October and peaked in mid-July. Our data suggest that filbertworm damage occurs during a longer period than previously believed and varies considerably between cultivars. Nut hardening in later summer does not seem to inhibit infestation, whereas thicker shells seem to

reduce the success of neonate larvae to penetrate the nut. However, there could be other factors influencing infestation success, such as husk stickiness.

28PO. YEAR-ROUND IPM PROGRAMS SUPPORT PEST MANAGEMENT DECISIONS FOR CALIFORNIA CROPS

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The UC Statewide Integrated Pest Management Program (UC IPM), with UC Agriculture and Natural Resources authors, produces the UC IPM Pest Management Guidelines, UC's official recommendation for managing pests in agriculture. The Guidelines cover specific crops and are organized by pest, leaving the user to determine what actions need to be taken for a complex of pests and when. To improve the Guidelines and promote whole IPM programs over management of single pests, Year-Round IPM Programs (YRPs) were developed. They guide growers and pest control consultants through a year of monitoring, prevention, and management practices required to carry out a comprehensive IPM program. The YRP includes pest identification photo guides and example monitoring forms that can be taken out to the field and used for record keeping. The YRP supports major pest management decisions by tying together the Guidelines and other decision-making tools such as the Degree-Day Calculator or Powdery Mildew Index. These programs serve as the foundation for USDA Natural Resources Conservation Service conservation plans by promoting practices to reduce negative impacts on water quality and other environmental issues. YRP checklists and forms provide documentation to support NRCS incentive programs. We currently have 17 YRPs on crops such as almond, apricot, citrus, grape, and tomato.

29PO. AQ6047: A UNIQUE AND IMPROVED STRAIN OF *STREPTOMYCES GALBUS* WITH INSECTICIDAL ACTIVITY

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AgraQuest is a company committed to discover and develop novel natural product solutions for pest management. Natural products are substances produced by microbes, plants and other organisms. Many secondary metabolites show bioactivity against important insect pests in agriculture. AQ6047 is a patented strain of *Streptomyces galbus* that exhibits insecticidal activity against Lepidoptera. A key step in product development was to determine if the insecticidal activity could be enhanced by classical mutation and fermentation optimization. The insecticidal activity of AQ6047 was determined by LC_{50}

in a 96-well plate assay and Leaf Disk Assay (LDA) using beet army worm (*Spodoptera exigua*) in greenhouse and small-plot tests. The bioassay results from LC_{50} and LDA confirmed that through fermentation optimization, we have increased the bioactivity by 35 fold and reduced the application rate from 174 liters to 5 liters of whole broth per acre. In addition to the fermentation optimization we also developed a prototype wettable powder (WP) formulation that provides 70 to 80% control when used at one to three-lbs per acre against lab grown *S. exigua* on excised Chinese cabbage leaves.

30PO. *ALTICA LITIGATA*, A FLEA BEETLE ATTACKING NATIVE AND EXOTIC WATER PRIMOSE IN CALIFORNIA.

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The flea beetle, *Altica litigata*, has been found defoliating both native and exotic water primrose, *Ludwigia* spp., in California. The adults and larvae feed primarily on the vegetative portions of the plants, often causing heavy skeletonization of the canopy. In some locations, beetle densities can reach extremely high levels causing total leaf loss. This work assesses the general life history and developmental biology of this weevil in Northern California and estimates levels of defoliation caused by different population densities under controlled conditions. The effect of environmental conditions, particularly temperature and soil moisture has been assessed on the prate of defoliation and a model developed to project defoliation under different weather patterns. Consideration is given as to the potential of this insect to be used in augmentation and/ or conservation biological control efforts.

31PO. ALTERNATIVE PREY AND BIOLOGICAL CONTROL OF LYGUS BUGS (HEMIPTERA: MIRIDAE) IN ALFALFA SEED

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Lygus bugs (Hemiptera: Miridae) are the most important insect pests in alfalfa seed production in the U.S. and are managed primarily with organophosphate, carbamate and pyrethroid insecticides. Effective biological control could help reduce negative impacts of lygus bug management on pollinators of alfalfa, and lygus bug natural enemies, and delay or prevent the development of insecticide resistance. Two major predators of lygus bugs in alfalfa seed are bigeyed bugs (*Geocoris* spp.) and damsel bugs (*Nabis* spp.). There is little information concerning the influence of alternative prey on lygus bug biological control provided by these generalist predators. The goals of this study were to conduct greenhouse experiments determining 1) the impact of bigeyed bugs and damsel

bugs alone and in combination on lygus bug (*Lygus hesperus* (Knight) populations in the presence and absence of alternative prey (pea aphid, *Acyrthosiphon pisum*). Our results to date have shown that higher lygus bug survival is associated with a combination of high aphid numbers and no predators, while the lowest lygus bug survival was associated with high numbers of predators in combination.

32PO. IMMUNOLABEL RETENTION BY EGG AND LARVAL STAGES OF DIORHABDA ELONGATA (COLEOPTERA: CHRYSOMELIDAE)

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Diorhabda elongata Brullé (Coleoptera: Chrysomelidae) egg masses were exposed to rabbit or chicken Immunoglobulin G (IgG) and assayed for label retention in a laboratory study. A subset of marked eggs were reared, allowing *D. elongata* larvae to be tested for label transfer. Results indicate that egg masses were readily labeled and maintained a strong absorbance value throughout the testing period. However, label retention by larvae was variable. Our results will be discussed in the context of future studies assessing natural enemies of and dispersal by *D. elongata*.

33PO. A THOUSAND POINTS OF FLIES: DIGITAL PHOTO SURVEY OF CATTLE PEST FLY ABUNDANCE IN WASHINGTON

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Horn fly and face fly are key pests of pastured beef cattle. Annual U.S. production losses due to these two flies are estimated to be over $1 billion. Horn fly biting stresses cattle, leading to reduced calf weight gain and milk production. Face fly is an indirect pest that transmits the causative bacteria for pinkeye. An accurate means of estimating fly populations is important, as pest population helps determine pest management strategies. The standard method for estimating fly populations on cattle is to visually count the flies on 10 to 15 animals in the herd. However, the accuracy of fly population estimates obtained through direct visual counts is questionable because flies and animals are constantly moving. In 2008, we estimated flies in two ways: using standard visual counts and using digital photography. Photos of the sides and faces of bovines were captured and placed into PowerPoint software. A grid was overlaid on side images to facilitate counting of flies. For face flies, estimates of fly abundance from direct visual counts

versus photo counts were comparable. In contrast, horn fly abundance was grossly underestimated with direct visual counts, with upwards of five times as many flies being counted from the digital images. Development of this fly population estimation tool will continue in 2009; we anticipate that it will prove very useful for research scientists as well as cattle ranchers.

34PO. MONITORING OF INSECTICIDE SUSCEPTIBILITY AND RESISTANCE IN FIELD-COLLECTED STRAINS OF *BLATTELLA GERMANICA* (ORTHOPTERA: BLATTELLELIDAE) IN R.O.K.

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The resistance and susceptibility of *Blattella germanica* to insecticides were evaluated under laboratory conditions using 8 insecticides. A susceptible strain and eight field strains in Korea of the German cockroach were used. The insecticides included 5 pyrethroids and 3 organophosphates. Based on their LC_{50} values, marked regional variations of insecticide resistance and susceptibility were observed. Six field-collected strains of *B. germanica*, excepting for the Gun-san and Gwang-ju strains, exhibited very high levels of resistance to pyrethroids such as esfenvalerate, bifenthrin and deltamethrin [Resistance Ratio (RR): esfenvalerate,320; bifenthrin, 240; deltamethrin, 160]. However, chlorpyrifos showed very higher levels of resistance on Gun-san and Gwang-ju strains of *B. germanica* than other organophosphates [Resistance Ratio (RR): Chlorpyrifos,150]. In the comparison of the susceptibility of the eight insecticides on the eight cockroach populations, the cockroach strains from Dong-hae, In-cheon, Dae-jeon and Dae-gu showed the highest susceptibility to chlorpyrifos with LC_{50} value of 0.01, 0.02, 0.02, 0.01μg, respectively. However, the cockroach strains from Gun-san, Bu-san and Cheon-an exhibited the highest susceptibility to chlorpyrifos-methyl with LC_{50} value of 0.04, 0.02, 0.05μg, respectively. Chlorpyrifos showed higher susceptibility than permethrin on the cockroach strain from Gwang-ju, Dae-jeon and Dong-hae with 160, 105, 320 fold of susceptibility rates ($SRLC_{50}$), respectively. The chlorpyrifos showed higher 320 folds of susceptibility than esfenvalerate on the cockroach strain from Dae-gu.

These results indicate that careful selection and rotational use of these insecticides might result in continued satisfactory control against field populations of *B. germanica* (L.).

35PO. INTRASPECIFIC AND INTERSPECIFIC MATE ATTRACTION IN PRAYING MANTIDS

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Sexual signaling often involves a degree of gamesmanship between males and females. In sexually cannibalistic species such as the bordered mantid *Stagmomantis limbata,* this game becomes deadly, as the female may attack and devour arriving males. We tested whether food-limited females emit pheromones as a foraging strategy (i.e., to lure in males as food) through a field experiment in fall 2008 in Bishop, California. We set out well-fed and poorly-fed females in covered screen cages to compare the number of male arrivals (12-fold replication of treatments). Well-fed females attracted significantly more males than poorly-fed females; no poorly-fed female attracted a male. Curiously, we also found males of a heterospecific mantid *(Mantis religiosa)* on the females' cages. To examine interspecific attraction, we set out covered field cages of females of three mantid species *(S. limbata, M. religiosa, Iris oratoria)* and released males of four mantid species *(S. limbata, M. religiosa, I. oratoria, Stagmomantis californica).* The only instances of interspecific attraction were *M. religiosa* males arriving on the cages of *S. limbata* females. We supplement these results with observations of *M. religiosa* males mounted on *S. limbata* females in nature. To account for this apparent interspecific attraction, we suggest similarity between female pheromones in *M. religiosa* and *S. limbata.*

36PO. FITNESS ESTIMATES FOR MASS REARING *Lygus lineolaris* (PALISOT DE BEAUVOIS) (HETEROPTERA: MIRIDAE) ON THE NI DIET AND MODIFICATION OF THE NI DIET

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The tarnished plant bug is an important economic pest with a wide range of crop hosts; including cotton, alfalfa, safflower, and beet. A modification of NI Diet for mass rearing *Lygus lineolaris* (Palisot de Beauvois) was developed in order to improve biological fitness. This modified NI diet has been used to mass rear and maintain several consecutives generations of *L. lineolaris*. Fitness values for fecundity, fertility, hatchability, and adult survival of *L. lineolaris* reared on the modified NI diet were greater than those obtained for *L. lineolaris* reared on the current NI diet.

37PO. MASS FITNESS ESTIMATE FOR MASS REARING *Lygus lineolaris* AND *Lygus hesperus* (HEMIPTERA: MIRIDAE) USING THE MODIFIED NI DIET

Maribel Portilla and Doug Streett

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The western tarnished plant bug, *Lygus hesperus* Knight and the tarnished plant bug, *Lygus lineolaris* Palisot de Beauvois (Hemiptera: Miridae) are very destructive pests and their economic impact spans several cropping systems in North America. In fact, over half of the cultivated plant species grown in the United States are listed as host plants for tarnished plant bugs. *L. hesperus and L. lineolaris* have been maintained for several years at the National Biological Control laboratory using the artificial NI diet. Recently, a new modified diet has been developed to improve fertility and fecundity for both Lygus species. This investigation shows the fitness estimates of *L. hesperus and L. lineolaris* reared on the modified NI diet. Daily egg production of *L. hesperus* decreased after day 7 of oviposition, whereas *L. lineolaris* maintained a constant egg production for 20 days. However, cumulative gross fecundity was significantly higher for *L. hesperus* than it was for *L. lineolaris*.

38PO. REQUIEM: A NOVEL PLANT EXTRACT – BASED INSECTICIDE FOR PLANT PEST MANAGEMENT

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Requiem 25EC is a novel plant-extract-base insecticide/miticide. The product was registered by the U. S. EPA in December of 2008. The state registration process is ongoing. Requiem is based on an extract of the essential oil of *Chenopodium ambrosioides,* near *ambrosioides* – a plant closely related to common lambsquarter – whose center of origin is Central America. The refined product contains compounds representing a range of modes of action, the major ones being; disruption of the cuticle, degradation of the tracheal lining and repellency. It has significant activity on soft bodied insects and spider mites. It is safe to many beneficial insects and mites. It is short-lived in the environment and is safe to mammals. This presentation will provide background on the development of the product product and bioassay information confirming its efficacy in various crop-pest complexes.