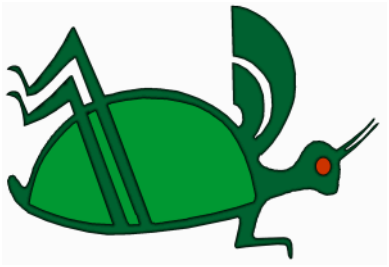
ABSTRACTS



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DESIGNING BIODIVERSE, PEST SUPPRESSIVE AGROECOSYSTEMS THROUGH HABITAT MANAGAMENT

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Agricultural monocultures are genetically uniform and species-poor systems representing an extreme form of simplification of nature's biodiversity, as monocultures advance at the expense of natural vegetation, a key landscape component that provides important ecological services to agriculture such as natural mechanisms of crop protection. In such situations farmers and researchers are faced with a major ecological dilemma arising from the homogenization of agricultural systems: an increased vulnerability of crops to insect pests and diseases, which can be devastating when infesting uniform crop, large scale monocultures. Monocultures may have temporary economic advantages for farmers, but in the long term they do not represent an ecological optimum. In this paper, we explore practical steps to break the monoculture nature of industrial agroecosystems and thus reduce their ecological vulnerability, by restoring agricultural biodiversity at the field and landscape level. The most obvious advantage of diversification is a reduced risk of total crop failure due to invasions by unwanted species and subsequent pest infestations. The paper focuses on ways in which biodiversity can contribute to the design of pest-stable agroecosystems by creating an appropriate ecological infrastructure within and around annual and perennial cropping systems. Selected studies reporting the effects of intercropping, cover cropping, weed management, agroforestry and manipulation of crop-field border vegetation are discussed, paying special attention to understanding the mechanisms underlying pest reduction in diversified agroecosystems. This reflection is fundamental if habitat management through vegetation diversification is to be used effectively as the basis of Ecologically Based Pest Management (EBPM) tactics in sustainable agriculture.

MONARCH BUTTERFLIES IN CHANGING ENVIRONMENTS: PARASITES, MIGRATION, AND PHENOTYPIC VARIATION

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Native and introduced monarch butterflies populate islands and continents worldwide and occupy a subset of the range of their larval host plants. Although monarchs appear morphologically similar throughout most of their range, populations do not exist in uniform environments, and selection may operate on traits affecting migratory ability, response to different host plant species, thermal tolerance, and resistance to natural enemies. In this talk, I briefly review results from recent efforts to examine variation in each of these four traits among three N. American monarch populations. First, the prevalence of a protozoan parasite (*Ophyrocystis elektroscirrha*) varies widely among populations, ranging from near 0 to almost 100% infection. Host resistance to parasite

infection also varies among three North American populations, with highest resistance among monarchs from the eastern migratory population. Wing morphology is expected to differ in response to selection driven by long distance flight operating on some populations but not others, and data from laboratory-raised and wild-captured monarchs supports this hypothesis. Other traits likely to vary among populations are thermal tolerance, including host survival and development rates in response to different environmental temperatures, and host use traits with respect to different milkweed species. Whether or not, and to what degree phenotypic differences have accumulated among monarch populations is relevant to understanding their migratory ecology, interspecific interactions, and for predicting how monarchs might respond to future environmental changes.

EFFECT OF AN ALTERNATIVE HOST IN THE APHID-VECTOR DISTRIBUTION AND EPIDEMIOLOGY OF PLRV

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Even the most intense aphid control strategies may not prevent the spread of potato leafroll virus (PLRV) unless measures are also taken to keep virus-source plants within and outside the crop at a minimum. Hairy nightshade, *Solanum sarrachoides* is a solanaceous weed abundantly distributed in potato ecosystems of Idaho, the largest potato producing state in the U.S. It is a preferred host for green peach aphid (GPA) *Myzus persicae*, considered the most effective vector of PLRV. Our laboratory experiments confirmed that GPA can transmit PLRV to hairy nightshade and that non-viruliferous aphids can become viruliferous after feeding on infected nightshades. We investigated whether PLRV-infected nightshades would attract GPA and also how this attraction would compare with the one produced by infected potatoes. Field trials were conducted to study the role of *S. sarrachoides* on vector distribution and PLRV epidemiology. Aphid counts and disease progression were monitored at weekly intervals. Results revealed that plots with nightshades recorded an increased number of aphids and also had higher number of PLRV infected potato plants. A preference study revealed increased preference of winged GPA to PLRV-infected *S. sarrachoides*. Field-collected nightshade plants were also found to carry PLRV and in other viruses such as PVY and PVX. Our findings thereby suggest that *S. sarrachoides* might play a major role in the epidemiology of PLRV in the potato ecosystem.

DIAGNOSTIC PCR PROCEDURES TO IDENTIFY INTERNAL FRUIT-FEEDING INSECTS OF POME FRUITS

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A diagnostic PCR method was developed for differentiating among the North American internal apple-feeding pests *Cydia pomonella* (L.), *Grapholita mol*esta (Busck), *Grapholita prunivora* (Walsh), and *Grapholita packardi* Zeller. Consistent and diagnostic differences were observed among the species in two regions of COI from which forward and reverse primers were designed to amplify a 112-116 bp segment of the gene. The primer sets selectively amplify DNA from specimens of diverse geographic origin for each corresponding target species. Protocols are available for conventional and quantitative PCR (qPCR), the latter being substantially faster. The method was validated as a decision making tool for quarantine identifications for Mexico and this can be extended to other importing nations. Ongoing efforts to develop diagnostic PCR primers to differentiate Rhagoletis pomonella and R. zephyria are also presented. Current, nearly complete diagnosis requires restriction analysis of two gene regions, a mitochondrial and a nuclear gene.

THE GLASSYWINGED SHARPSHOOTER GETS NO WELCOMING LEI OF ALOHA FROM THE ISLAND PARADISE

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In May 2004, adults of an unknown leafhopper were accidentally discovered in Hawaii at Pearl City on the island of Oahu. Brought to the attention of the Hawaii Department of Agriculture (HDOA), the insect was identified as the glassywinged sharpshooter (GWSS), Homalodisca coagulata (Say) (Homoptera: Cicadellidae). The GWSS is a potential threat to Hawaiian agriculture because it vectors the bacterial pathogen, Xylella fastidiosa, which is the causal organism of Pierce's disease in grapes, citrus variegated chlorosis, alfalfa dwarf, and scorch diseases in almond and some ornamental plants. Field surveillance with a GPS system indicated that the GWSS is more widespread in leeward Oahu than previously believed. Recently, the GWSS was detected at Heeia in Kaneohe, which is the first locality record for this pest on the windward side of the island. Initial DNA fingerprinting at the USDA-ARS laboratory in Weslaco (Texas) did not suggest a common genetic tie between the GWSS in Hawaii and those found in the continental U.S. and Tahiti (French Polynesia). More than 30 plants have so far been documented as GWSS hosts. A hymenopterous parasitoid was recently found attacking GWSS eggs.

Identified as Gonatocerus sp. (Family Mymaridae), it appears to be a very effective GWSS parasitoid. Field data indicate a parasitism rate of >90%. As field surveys progress, the impact of the parasitoid on GWSS infestations is becoming more and more apparent.

INVESTIGATIONS IN THE MANAGEMENT OF SAN JOSES SCALE DIASPIDIOTUS PERNICIOUS (COMSTOCK) (HOMOPTERA:DIASPIDIDAE) WITH HORTICULTURAL MINERAL OIL

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San Jose scale Diaspidiotus perniciosus (Comstock) control was studied over a four-year period on four cultivars of plum in central California. The results of this study demonstrated that San Jose scale is effectively managed with a horticultural mineral oil application during the dormant season. No additional insecticide is required. Control of San Jose scale is influenced by the amount of oil applied per acre, the concentration of oil in the spray tank, and the timing of the oil application. In these studies, best results were obtained with 8 gallons of horticultural mineral oil in 400 gallons of water mixture per acre. If 100 gallons per acre is applied, a minimum of 8 gallons of oil provided adequate control of San Jose scale on early harvested cultivars. The harvest date of plums also influenced the severity of San Jose scale infestation. Plum varieties harvested in late June and early July are less infested than those harvested in August or September. There is also a close relationship between infested spurs collected during the winter and subsequent fruit infestation with fruit harvested in July, August and September.

BREAKING THE DISEASE CYCLE: THE BIOLOGY OF GLASSY-WINGED SHARPSHOOTER/XYLELLA INTERACTIONS

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The grape strain of *Xylella fastidiosa* (*Xf*) causes Pierce's disease (PD) in grapevines and is transmitted by the glassy-winged sharpshooter (GWSS), *Homalodisca coagulata*. Understanding the interactions between the insect, plant, and pathogen are necessary to develop innovative strategies to negatively impact pathogen proliferation. Symbiotic control employs symbiotic bacteria to deliver anti-*Xf* compounds to disrupt transmission of the pathogen to new host plants. *Alcaligenes xylosoxidans* var. *denitrificans* (*Axd*) is a

prime candidate for control of PD because it inhabits the foregut of GWSS and the xylem of plants providing access to *Xf*. Candidate toxins that could be delivered by *Axd* have been shown to disrupt pathogen transmission.

WATER QUALITY PRACTICES PLANNING - POTENTIAL FOR REDUCING AGRICULTURAL NONPOINT SOURCE POLLUTION ON THE CENTRAL COAST

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The Monterey Bay National Marine Sanctuary is the largest marine protected area in the USA, including more than 5,000 square miles along the Central Coast of California. Runoff water, lost from agricultural lands in coastal watersheds and transported to the Sanctuary waters, may carry sediment, nutrient, and pesticide pollutants. Reduction of pollutants requires identifying site-specific resource concerns, their connection to pollution potential, and selection of site appropriate management practices. For example, sediment management practices may be the most appropriate mitigation to prevent movement of sediment-bound pesticides into surface waters. Additionally, water quality management practices must be integrated with production goals.

To improve the availability and relevance of technical information regarding water quality practices planning to irrigated agriculture, the University of California Cooperative Extension (UCCE), in partnership with the USDA Natural Resources Conservation Service (NRCS), have adapted and are extending the Farm Water Quality Planning Short Course to industry-led Watershed Working Groups and other producers. During the Course, producers learn water quality regulations, techniques for site-assessment of nonpoint source pollution problems, sediment, pesticide, and nutrient management goals, methods for recognizing practices that are already in place that protect water quality, management practices that may be selected based on local conditions and crop types, and practice evaluation methods. The peer-reviewed Farm Water Quality Curriculum is available online at http://waterquality.ucanr.org.

Participation in the Farm Water Quality Planning Short Course and development of an individual Farm Plan enables growers to comply with components of the Conditional Waiver for Discharges from Agricultural Lands, recently adopted by the Central Coast Regional Water Quality Control Board. To date, more than 750 growers (including growers in 23 Watershed Working Groups facilitated by the Coalition of Central Coast County Farm Bureaus) have participated in training on the development and implementation of farm water quality management plans.

UNDERSTANDING HOMALODISCA COAGULATA DISPERSION AND DETECTING XYLELLA FASTIDIOSA IN VECTORS: KEYS TO DISEASE MANAGEMENT

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Homalodisca coagulata (Say) (Hemiptera: Cicadellidae) is an invasive insect pest new to California that is a vector of the plant pathogenic bacterium *Xylella fasatidiosa* Wells et al. The most important of the diseases caused by *X. fastidiosa* in California is Pierce's disease of grapevine. Two aspects of the biology of *H. coagulata* make it a more devastating vector of Pierce's disease than vectors that are native to California. First, its dispersal capabilities and flight behavior make a larger proportion of a vineyard susceptible to inoculation relative to the case with native vectors. Second, its ability to feed on woody grapevine tissue apparently allows it to spread the pathogen from grapevine to grapevine (secondary spread), in addition to spreading the pathogen from outside vineyards into vineyards (primary spread) like native vectors. This substantially increases the rate of disease spread. Through an understanding of *H. coagulata* horizontal and vertical dispersion we have developed a unique management tactic consisting of a screen barrier to reduce insect movement from hosts on which they reproduce to crops requiring protection. Current studies are focusing on the detection of *X. fastidiosa* in *H. coagulata* to ascertain the importance of secondary disease spread, and determine when plant protection tactics could be most optimally deployed.

ORGANIZING AND PRIORITIZING EFFORTS TOWARD WEST NILE VIRUS IN A RURAL COUNTY

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The expected arrival of WNV into California has been on our minds here in Monterey County since we first noticed how rapidly it began spreading across the United States. The Northern Salinas Valley Mosquito Abatement District (NSVMAD) incorporates 458 Square miles of the Northern part of Monterey County and has not had any virus activity since about 1968. Our weather is cooler and sources are limited to two large areas, the Elkhorn Slough and the Salinas River and of course many domestic sources. The NSVMAD has always tried to have a proactive approach to Mosquito control. We have used heavy equipment to eliminate sources and a weed control program to maintain them. In preparation for West Nile Virus we have added a tractor mounted mower for controlling tulles. This source reduction program has cut the number of sources dramatically. It has also cut our staff over the years from 15 employees to our current 8 employees, many with more than one job title.

The 2005 season is expected to be the big year for virus activity here in Monterey County. It is not expected to reach anywhere near the levels expected in other areas of the State. During the winter months we will be doing some additional adulticide treatments of our over wintering mosquitoes in some of our storm drains. We are also planning on hiring some additional summer help to deal with the dead bird program and other added duties.

SEED TREATMENT INSECT CONTROL IN SPRING WHEAT, 2004

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Pacific Coast Wireworm (WW): *Limonius canus* LeConte. Russian wheat aphid (RWA): *Diuraphis noxia* (Mordvilko). An experiment consisting of a RCB of 6 seed treatments (4 replicates) was seeded using a small plot drill on 7 Apr (60 lb acre) at the USDA-ARS Western Regional Plant Materials Introduction Center at Central Ferry, WA. Seeding was into failed winter wheat which had been seeded on sweet corn ground to encourage wireworm presence. The crop emerged on 12 Apr. Wireworm damage was evaluated by mean plant stand counts per 18 inches of row at 10 DAPE. Mean grain heads per plant were counted prior to harvest as a measure of plant vigor. Differences in plant stand varied between treatments with the two rates of Poncho and Gaucho 480 0.32 fl/oz cwt being significantly higher than the other treatments and UTC.
Heads per plant were significantly higher for the two rates of Poncho compared to the other treatments and the UTC. Since RWA appeared after plant stand and head counts were established, differences in plant stand are attributed to wireworm attack on the seedling plants.

RWA appeared at just prior to anthesis, and at 48 DAPE counts of mean percent RWA infested tillers were made. Yield data in bu per acre were collected by small plot combine 22 Jul.

All 5 seed treatments provided better control of RWA compared to the UTC. Poncho™ 600 provided slightly better yields compared to the 0.32 fl oz/cwt Gaucho 480 treatment. These 3 treatments were better than the other treatments, and the UTC.

DETERIORATION OF THE PRIME OVERWINTERING HABITAT IN THE MONARCH BUTTERFLY BIOSPHERE RESERVE IN MEXICO

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Aerial photography, Landsat and Ikonos satellite imagery and ground reconnaissance document that four of the principal overwintering areas of the eastern North American population of the monarch butterfly (*Danaus plexippus* L.) are deteriorating due to illegal logging. Several specific overwintering sites studied since 1977 have been eliminated in the Chivati-Huacal and Cerro Pelon massifs, while deleterious encroachment has occurred on the Sierra Campanario and Sierra Chincua massifs. The extent of logging in the latter area increased extensively in 2003- 2004. All of these overwintering areas were protected by Presidential decree in 1986, and by a new Presidential decree in 2000 that created The Monarch Butterfly Biosphere Reserve. The prognosis for the long term survival of the overwintering phenomenon of the monarch butterfly in Mexico is poor.

PHYLOGENETICS AND EVOLUTION OF THE FIGITIDAE (HYMENOPTERA: CYNIPOIDEA)

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A comprehensive phylogeny of the Figitidae (Hymenoptera: Cynipoidea) is presented based on simultaneous analysis of molecular (28S-D2 and D3, COI and 18S-E23) and morphological data analyzed by parsimony and Bayesian inference. A total of 94 genera and 168 species were sampled. Partitioned Bremer support, sensitivity analysis and bootstrap support provide good measures of robustness for all major clades. All subfamilies are found to be monophyletic except for Figitinae. *Lonchidia* renders Figitinae paraphyletic; this genus is likely a distinct lineage outside of Figitinae. *Melanips*, presently in Figitinae, was consistently found to be the basal most member of the Aspicerinae. Non clock-like estimates of divergence times of all major lineages suggests that most figitid groups diverged in the mid to late Cretaceous except for the Eucoilinae which diverged in the Eocene (44 mya). The divergence of major lineages of Eucoilinae, the most diverse and successful of all figitid groups, has been estimated to follow the divergence estimates of their hosts, schizophoran Diptera (48-51 mya). The presence of a morphological feature that improves the chances of successful oviposition, the ovipositor clip, was surveyed across all Figitidae. This clip was found on figitines and eucoilines that attack 'free-living' schizophoran Diptera in various habitats, and is likely a key feature in elucidating the evolutionary history of this ubiquitous yet poorly understood group.

POPULATION DYNAMICS AND RELATION BETWEEN ABUNDANCE AND DAMAGE IN FIGS, PISTACHIOS, AND ALMONDS

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The navel orangeworm (NOW) is an important pest of California crops including almonds, pistachios, walnuts, and figs; crops worth an estimated $1.28 billion in 2001, and which suffered navel orangeworm damage estimated at over $100 million in that year. Larvae do not develop on foliage, but feed exclusively on drying fruit or nuts. Until recently its sex pheromone has defied characterization, and that has harmed characterization of abundance in various crops as well as mating disruption as a pest management tactic against this pest. Over the last several years we have used flight traps with unmated NOW females as a pheromone source to compare abundance and population dynamics between figs, almonds, and pistachios in the Central and Southern San Joaquin Valley, and we have taken fruit samples at harvest to compare NOW abundance and damage between these crops. NOW males are more abundant in pistachios than in the other crops, particularly during the second flight from mid-June to mid-July, but pistachios and figs have little economic injury at levels of adult abundance which result in severe NOW damage and economic loss in almonds.

COMPARING SPRING WHEAT VARIETIES FOR VOLATILE PRODUCTION AND OVIPOSITION PREFERENCE BY THE WHEAT STEM SAWFLY

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Three varieties of spring wheat commonly grown in Montana were studied to determine whether significant differences occur in their volatile production of behaviorally active compounds for the wheat stem sawfly, *Cephus cinctus* Norton. We also investigated wheat stem sawfly oviposition preference among the three varieties to provide further insight into sawfly oviposition behavior.

Three spring wheat varieties were chosen for the study: ‘Reeder’, ‘McNeal’, and ‘Conan’. The volatiles emitted by individual wheat plants of these spring wheat varieties were collected and analyzed using gas chromatograph – mass spectrometry (GCMS). The amounts produced of those compounds known to affect sawfly behavior were compared for the varieties: cis-3-hexenyl-acetate, ocimene, 6-methyl-5-hepten-2-one, and cis-3-hexenol. Cage choice tests were performed to compare the oviposition preference of the sawflies in these three different spring wheat varieties in the greenhouse.

'Reeder' produced significantly higher amounts of the behaviorally active compounds and female sawflies laid significantly more eggs in 'Reeder'. The fact that female sawflies preferred to lay eggs in the variety that produced more volatiles, suggests that these variables might play a key role in the selection of oviposition sites by female sawflies.

FUMIGATION OF FLOUR MILLS TO MANAGE RED FLOUR BEETLE: ASSESSMENT OF TREATMENT EFFICACY

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Methyl bromide is still widely used in flour mills for the suppression of stored-product insect pests; primarily the red flour beetle Tribolium castaneum. Use of this fumigant is being phased out and development and adoption of alternative control tactics, such as sulfuryl fluoride or heat, has been made more difficult due to the extremely limited published field data on action thresholds, efficacy, and rate of population rebound. Here, we evaluate the impact of multiple fumigations with methyl bromide or sulfuryl fluoride on red flour beetle populations in multiple flour mills. Red flour beetle population levels were assessed using either direct counts of insects from product samples, direct counts of insects sieved from the product stream (i.e., tailings samples), or from pheromone baited trap captures. From this data, average levels at time of treatment, percent decrease in number following treatment, and rate of rebound were determined. Influence of season and pest density on efficacy and rebound were also evaluated. From the compilation of this type of monitoring data we can begin to develop a better understanding of the impact of fumigation on pest populations and improve the selection, timing and application of pest suppression tactics in flour mills.

WHAT IF: AVOIDING AND FIXING PROBLEMS IN CROP PROTECTION

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Lessons learned in the field, in the courts, and in research labs can help us avoid certain crop protection problems and fix some that recur. Field workers can be better protected against exposure to pesticides. Agricultural commodities can be better protected against excessive residues, both biological and chemical. Dangerous spills can be avoided. Long-standing crop protection puzzles can be solved. Extension and regulatory contributions to crop protection can be enhanced. What if: looks at a number of examples from the past, and implications for the future.

REDUCING PESTICIDE SPRAY DRIFT AND RUN-OFF INTO SURFACE WATERS OF OREGON'S HOOD RIVER VALLEY

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There are approximately 15,000 acres of fruit orchards in the Hood River Valley requiring intensive pest management programs. Historically, these programs have relied heavily on the use of broad-spectrum pesticides including organophosphate (OP) insecticides for control of arthropod pests. In 1999, water quality monitoring conducted by the Oregon Department of Environmental Quality (DEQ) indicated exceedences of state water quality standards for pesticides, including chlorpyrifos and azinphos-methyl, in area streams. Most pesticide applications are made with radial airblast sprayers. Drift from orchard spraying and runoff from mixing and loading sites were recognized as likely modes of water contamination. An intensive outreach program supporting grower adoption of orchard pest management practices designed to protect water quality while providing effective orchard pest management was initiated by the OSU Mid-Columbia Agricultural Research and Extension Center (MCAREC) and the Hood River Grower-Shipper Association (HRGSA). The outreach program combined the efforts of the HRGSA Best Management Practices (BMP) Project, which focused on BMPs for pesticide handling and application, and the Areawide II Pest Management Project, a complimentary program focusing on alternatives to OP insecticides and integrated pest management (IPM) programs for key tree fruit pests.

Information was developed to support grower adoption of the BMPs and IPM programs. This information was communicated through presentations during annual grower meetings, field days, pesticide education trainings, one-on-one field visits, newsletters, and a website (http://community.gorge.net/hrgsa/BMPproject.html). Additionally, a grower handbook was developed that integrates the information on both the BMPs and IPM programs. One of the main features of the handbook is an illustrated guide to best spray practices. These include cultural practices, mixing and loading, sprayer maintenance and calibration, and spray application practices for reducing water contamination from drift and runoff. These are practical, low- or no-cost, common sense approaches to pesticide use. A companion PowerPoint module was developed for presentations in pesticide education sessions. Handbook information on IPM practices includes alternatives to OP insecticides (including pheromone mating disruption for codling moth control) and an illustrated guide to accessing and using Web-based phenology models for orchard pest management.

A survey of growers conducted in 2004 indicated increased knowledge of and adoption of BMPs. Water quality monitoring subsequent to 1999 by OSU and DEQ scientists indicated generally reduced frequency and concentration for chlorpyrifos detections, but increased incidence of azinphos-methyl detections exceeding water quality standards.

The latter probably reflects a recent reversal in a multi-year trend toward widespread adoption of pheromone mating disruption for codling moth control.

The BMPs for pesticide use and IPM programs including alternatives to chemical control are considered to be important components of a long-term program for reducing pesticide loading of the environment while providing effective pest management. The development and adoption of improved pesticide application technologies is a necessary additional component. Funding for the HRGSA BMP Project expired in April 2004. The outreach program continues through ongoing Extension activities of the MCAREC and outreach efforts of the HRGSA.

CHARACTERIZATION OF FACULTATIVE BACTERIA IN THE HINDGUT OF *FRANKLINIELLA OCCIDENTALIS* (PERGANDE), WESTERN FLOWER THRIPS

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Facultative bacteria have been discovered in the hindgut of the Western flower thrips (WFT), *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). Several isolates of the bacteria from thrips in the Netherlands have been characterized and placed in *Escherichia,* although their classification was not fully resolved. These bacteria can be cultured outside thrips and are horizontally transmitted among WFT. We found similar bacteria in Hawaiian WFT populations and have begun characterizing them. Bacterial phylogeny based on the highly conserved 16s gene reveal that the bacteria in WFT populations from Hawaii are similar to those found in WFT from the Netherlands. Preliminary phylogenetic analysis shows that the closest relatives to the bacteria from both WFT populations are plant pathogens in *Erwinia* rather than in *Escherichia*. Our phylogenetic characterization will provide a foundation for thorough WFT bacteria classification and will play a role in revealing the relationship between thrips and their bacterial symbionts.

A PAN-PACIFIC ODYSSEY: THE DIVERSIFICATION OF POLYNESIAN WEEVILS IN THE GENUS *RHYNCOGONUS* (CURCULIONIDAE: ENTIMINAE)

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Large, flightless, broad-nosed weevils constitute a conspicuous element of many oceanic island faunas, despite their seemingly poor dispersal capabilities. The genus *Rhyncogonus* is one such genus, comprising 112 described species, broadly distributed across Polynesia

on some of the remotest islands in the world. Individual species are almost exclusively single island endemics and many remote islands are host to multiple endemic weevil species. Using a phylogenetic approach, an understanding of the tectonic history of the Pacific and oceanic island geomorphology, it is possible to test ideas about the origin of the group and to identify the roles of vicariance, dispersal and ecological shifts in the diversification of *Rhyncogonus*. A molecular phylogeny resulting from the analysis of 2,000 b.p of combined nuclear and mitochondrial sequence data is presented here for 60 ingroup species and 37 outgroup taxa. This reveals that, as suggested by morphology, *Rhyncogonus* has a sister genus in western Polynesia and so probably dispersed across the Pacific from the west. The deep divergences and long branch-lengths within the phylogeny indicate that this genus has a long history in the central Pacific, an observation consistent with the biogeographic trends across the phylogeny. Diversification appears to be the result of geographic isolation, due to both within-island vicariance and multiple independent colonizations. This has then been accompanied by morphological and ecological differentiation. This research is just one of the many systematic and phylogentic projects carried out by students linked with the Essig Museum of Entomology at U.C. Berkeley.Current research spans the Insecta and beyond, with fieldwork covering the globe.

HISTORY OF PEA APHID OUTBREAKS ON PEAS IN THE PALOUSE

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Field pea, *Pisum sativum* L., is a spring crop grown in rotation with cereal crops in eastern Washington and northern Idaho (Palouse region of the Pacific Northwest). The major insect pests of peas are the pea leaf weevil, *Sitona lineatus* (L.), pea seed weevil, *Bruchus pisorum* (L.), and the pea aphid, *Acyrthosiphon pisum* (Harris). An insect outbreak is an explosive increase in abundance over a relatively short period of time, a phenomenon first recorded in the 1930s and 1940s for the pea aphid on eastern Washington peas. During outbreak years, pea aphid-vectored viruses and feeding damage have been responsible for high pea seed losses in the Palouse. I developed a pea aphid outbreak index (0-4, where 0 equals 0-25% of pea fields with high populations and 4 equals > 76% of fields supporting high populations) based on suction trap counts, field sampling, incidence of virus epidemics, and grower contacts. Outbreaks (3 or 4 rating) have occurred on Palouse peas every seven (1983 to 1990) and six (1990 to 1996) years. In other years (1989, 1993, and 2004), pea aphid densities were high (2 rating), but did not reach outbreak levels (3 or 4 rating) between April and late-June.

THE PUBLIC HEALTH MEDICAL RESPONSE TO WEST NILE VIRUS

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The public health medical response to West Nile Virus (WNV) includes surveillance for human disease; education of physicians regarding diagnosis, laboratory testing, clinical management and public health reporting; coordination with laboratories to facilitate testing; coordination and information sharing with vector control, public outreach and education; and risk communication.

Santa Clara County had no WNV activity during 2003, and only one confirmed human case reported in 2004. However, because the extent of WNV activity was unknown at the beginning of the season, we embarked on an intensive physician education program to enhance appropriate diagnosis and reporting. Much of our ability to predict human disease activity depends on data collected through vector borne disease surveillance projects such as dead bird, mosquito, and sentinel chicken surveillance projects, as well as trends in other jurisdictions. Our ability to do effective public outreach, education and risk communication also depends on having timely vector control data. Although we can not predict for certain the severity of next year's WNV season, we do know that close coordination and timely data sharing between vector control and public health will be essential to an effective response.

USING HABITAT MANAGEMENT TO IMPROVE BIOLOGICAL CONTROL ON COMMERCIAL ORGANIC FARMS IN CALIFORNIA.

Ramy Colfer

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Mission Organics grows organic vegetables on over 6000 acres per year. A major group of pests that we encounter are aphids. One of the key strategies that we use to manage aphids is conservation biological control. Through research and observations, we determined that fostering syrphid populations was key to managing lettuce aphid populations in organically-grown romaine lettuce. Some key ecological factors that contribute to the effectiveness of syrphid biological control include high syrphid population abundance and wide spatial distribution. Sweet alyssum is found to be a good plant species for intercropping in our cropping systems. Evidence is presented that alyssum intercropping can improve the control of lettuce aphid populations by promoting syrphid population establishment.

PUBLIC'S PERCEPTION OF AND ROLE IN MINMIZING WNV. PANIC, CONCERN OR COMPLACINCY; HOW GOVERNMENTAL AGENCIES CAN AFFECT THE PUBLIC'S PERCEPTION OF WEST NILE VIRUS

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West Nile virus (WNV) is the fastest spreading vector-borne disease to ever hit the US. It spread from coast to coast in less than four years, sickened thousands and killed hundreds of people and several thousand birds. Even reptiles, normally not affected by encephalitis, have died due to WNV. In fact at least thirty-four (34) species of mammals have been affected by WNV.

Fear of the unknown is usually a cause of panic. Having only partial knowledge of a subject and not knowing where to go for more or correct information can be worse yet. Such is the case with WNV.

Keeping the public informed and updated is important. It helps keep panic under control while preventing complacency. The public needs to be made aware of the important role they play in the fight against WNV.

There are several methods of outreach available to accomplish this goal. Which methods are the most cost-effective? Who are the target groups? And most importantly, what is the message?

NOVALURON, A NOVEL IGR FOR CONTROLLING THE COLORADO POTATO BEETLE

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Colorado potato beetle (CPB), *Leptinotarsa decemlineata*, continues to be the most destructive insect pest of potato in North America and one of the most severe agricultural pests in the world in terms of insecticide resistance. Better CPB control could be achieved with integrated pest management (IPM), but most insecticides are non-selective, impeding development of CPB-IPM. Here we report on studies investigating the management potential of novaluron – a novel, low-rate, chitin synthesis inhibitor – against CPB.

In ingestion leaf-dip bioassays, novaluron (Rimon® 10EC) exhibited excellent activity against 2nd instar larvae (L2) (LC_{50}=0.42 ppm) of an insecticide-susceptible laboratory CPB strain, but was approximately an order of magnitude less toxic than imidacloprid (Admire® 240F), spinosad (Tracer® 480SC) and lambda-cyhalothrin (Matador® 120EC). Although good direct contact activity also was observed, LC_{50} values were 64-89 fold higher than those of the residual bioassays, depending the time of exposure, emphasizing that novaluron is more effective against CPB following ingestion of the molecule than through contact. Novaluron also was effective against eggs by direct contact. Hatch of eggs exposed to novaluron solutions ≥ 100 ppm was significantly reduced, as was the ability of emerged 1st instar larvae (L1) to moult. Although, L2 from eggs exposed to ≥ 100 ppm novaluron weighed significantly less than those from untreated eggs, L2 from eggs treated with 1 ppm novaluron weighed significantly more than those from untreated eggs, suggesting novaluron can have a hormetic effect on CPB larval development. The sublethal effects of novaluron on adult CPB of the insecticide-susceptible strain were also investigated. Adult mating pairs fed foliage treated with novaluron at 25 or 75 g AI/ha produced approximately 25% fewer egg masses and eggs/egg mass. Although embryos within eggs laid on treated foliage underwent substantial development, percent hatch (0.12-3.8%) was significantly less than hatch of eggs from females on untreated foliage (70%). In addition, male beetle longevity was reduced by about 50% when fed foliage treated with novaluron at 75 g AI/ha.

A field experiment was conducted to determine the efficacy of novaluron against CPB when used alone, or in rotation with imidacloprid. As expected, foliar applications of novaluron caused no significant reductions in adult CPB mortality. Although reduced fecundity in adults fed novaluron treated foliage was observed in laboratory experiments, no reductions to the number of egg masses per plant was found in the field experiment. Novaluron, whether applied first or after an initial novaluron/imidacloprid application, caused no reductions in the number of L1 but caused significant reductions in the number of L2. Further, development of 3rd (L3) and 4th (L4) instar larvae was almost completely suppressed throughout the trial. While control plots were completely defoliated by the end of the experiment, none of the other treatments had more than 10% defoliation.

Finally, experiments were conducted to determine the potential of CPB to develop resistance to novaluron before its widespread use in CPB management. L2 of an imidacloprid-resistant CPB strain exhibited low-level resistance (2.5-fold) to novaluron. The toxicity of novaluron to this strain was synergized by S, S, S-tributyl phosphorotrithioate but not by piperonyl butoxide, suggesting that esterase-based detoxification mechanisms were responsible for novaluron resistance. Bioassays with treated potato foliage found that a single novaluron application was highly persistent under field conditions. When fed foliage 35 days after treatment with novaluron at low or medium application rates, up to 85% of L2 from an insecticide-susceptible laboratory reared strain died. Thus, intense selection pressure for novaluron-resistant CPB may continue long after population densities have been reduced below an economic threshold level. In a national survey, the susceptibility of L2 to a novaluron diagnostic dose was determined for 27 different populations collected from 6 Canadian provinces in the summer of 2003. Despite no previous exposure to novaluron, mortalities at the

diagnostic dose ranged from 55-100%. Although novaluron possesses several important characteristics that may delay resistance development in CPB, these results emphasize the importance of using well-established resistance management practices to prevent/delay the development of novaluron-resistant CPB.

The results of these studies demonstrate the effectiveness of novaluron against CPB. In addition to demonstrated selective toxicity favoring non-target beneficial insects, many CPB populations have had limited exposure to chitin synthesis inhibitors, reducing likelihood of cross-resistance with conventional compounds. Novaluron could thus be a valuable tool in future CPB-IPM programs.

THE IMPACT OF MANIPULATING PLANT BIODIVERSITY IN CALIFORNIA VINEYARDS ON ARTHROPOD PESTS AND BENEFICIALS

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Development of novel approaches for Integrated Pest Management (IPM) systems has often relied upon research in organic or sustainable crops systems. California vineyards were at the forefront of many novel approaches developed in the 1950-70s, with vineyard insect pests the target of classical, augmentation, and conservation biological control, as well as many cultural control practices. Two popular methods to improve natural enemy impact has been the addition of ground covers or prune trees to increase plant biodiversity in the vineyard. Insect pest densities have, in fact, been lowered by this increase in plant diversity. However, the mechanisms behind lowered pest densities were not well understood. We studied the impact of ground covers on both insect densities and vine condition. Our results show that a combination of biotic and abiotic factors result in lowered leafhopper densities. Most important is the reduction in vine vigor that resulted from competition between the vine and ground covers for water and nutrients. The lowered vine vigor can result in lowered leafhopper densities because of poorer host condition.

IPM AND BIOLOGICAL CONTROL IN CALIFORNIA STONE FRUIT ORCHARDS

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Over the past 20 years, California stone fruit growers have seen remarkable changes in insect pest management approaches, with research developments that have reduced the

necessity of organophosphate insecticides for pest control. Here, we review the two common stone fruit insect pest groups (moth larvae and San Jose scale) to ask the question, "What has driven sustainable agriculture in stone fruit – improved biological control or insecticide materials." Stone fruit pests, particularly the oriental fruit moth and San Jose scale, have been the target of numerous biological control programs. Natural enemies of these pests are present in every California orchard and help to suppress pest populations. Still, we argue that recent advances in insecticide and pheromone control techniques have been resulted in a greater boost to natural enemy effectiveness then the use of techniques such as increasing farm biodiversity, augmenting natural enemy densities, or changing crop management practices. While it is well-known that progression of different pest species in stone fruit disrupted established biological control when broad spectrum insecticides, we suggest that organic stone fruit growers can best maximize the impact of natural enemies by using the most effective and specific insecticides available.

AUGMENTATION OF *GONIOZUS LEGNERI* TO CONTROL NAVEL ORANGEWORM – PARASITOID BIOLOGY IMPEDES SUCCESSFUL CONTROL

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We evaluated the effectiveness of augmentative releases of a parasitoid (*Goniozus legneri*) for control of navel orangeworm, a moth pest of almonds. Initial field research using commercial *G. legneri* release practices found no consistent differences in NOW infestation levels among release and no release controls. We determined much of the variation was due to the commercial release method of placing *G. legneri* pupae in gelatin capsules, which resulted in significant *G. legneri* mortality (up to 88%) from foraging ants and earwigs. To improve release methodology, we investigated *G. legneri* biology and the potential of adult *G. legneri* releases. Results showed *G. legneri* dispersed from the release point throughout the tree canopy and to distances up to 12 trees from the release site. We conclude that adult *G. legneri* can be released at only 2-3 locations per acre, thereby, reducing labor costs. We also found that the adult *G. legneri* is the primary overwintering stage, suggesting that post-harvest releases may have little impact on the following season's parasitoid densities if the *G. legneri* do not develop to the adult stage before temperatures decline. Laboratory studies showed that adult *G. legneri* can live for >100 days and deposit >50 eggs per female. However, the adult female's behavior of brood tending limits her reproductive potential in almond orchards with low or moderate navel orangeworm densities.

A COMPARISON OF DIETS IN SPRING ALFALFA FIELDS OF FEMALE COCCINELLIDS (COLEOPTERA: COCCINELLIDAE.)

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Alfalfa fields in Utah comprise habitat in which several species of lady beetles coexist. Currently the dominant species is *Coccinella septempunctata*, and introduced species. Several native species occur in low densities in alfalfa, though prior to the introduction and increase of *C. septempunctata* densities were high. This guild of lady beetles is primarily aphidophagous. In alfalfa, aphid prey densities fluctuate greatly throughout the growing season. When their densities are low, lady beetles must use an alternate prey source to survive. In spring alfalfa one alternative is the larval stage of the alfalfa weevil. At the outset of the Spring 2004 growing season aphid densities were extremely low, and peaked at one aphid per stem (via stem counts) just before mowing of the alfalfa began. Female lady beetles of all species were collected during the spring growing season prior to mowing. Frass was collected from each individual and was analyzed to determine prey usage. Diets of native and introduced lady beetles during this time will be discussed.

NEW PERSPECTIVES ON MIGRATION IN MONARCH BUTTERFLIES: INSIGHTS FROM LONG-TERM MONITORING AND CITIZEN SCIENCE

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In the past decade, multiple long-term monarch migration monitoring projects have been in place across eastern North America. Most are run by a combination of trained scientists, dedicated volunteers and citizen scientists. Journey North is an online program that recruits school children to track the monarch spring migration on a continent-wide scale. By comparison, more intensive monitoring programs have been established to track the fall migration of monarchs at single sites in Cape May, New Jersey, Chincoteague, Virginia, and Peninsula Point, Michigan. This talk will focus on several recent papers in print, press and review, highlighting results from each of these spring and fall projects. First, data from the Journey North program from 1997-2002 were used to document patterns of monarch recolonization of their breeding range in eastern North America. Results showed a remarkable consistency in this pattern from year to year. More recently, these data were used to generate new estimates of spring migration speed using GIS technology, pointing to distinct spring migration phases. Second, monitoring efforts focusing on fall migration through major monarch flyways provide evidence for long-term population trends, effects of environmental parameters on stopover patterns, and consistency in migration patterns among sites. At all three of the fall migration monitoring sites, volunteers count the number of monarchs seen during standardized daily censuses. At Peninsula Point, 7 years of monitoring data showed how daily

environmental conditions such as wind directions affect the numbers of monarchs that stop over at the site. Thirteen years of monitoring data from Cape May documented the timing and consistency of migration waves and elucidated long-term trends in the eastern population. Results showed fluctuating annual population sizes and an alarming drop in monarch numbers during the past 4 years. Finally, data from the Chincoteague project have been recently used to show that annual indices of monarch abundance between this and the Cape May site are similar. Each of these projects provides us with critical insights into the unique and endangered phenomenon of monarch migration in eastern North America.

EVIDENCE THAT FORAGING EXPERIENCE ALTERS THE MUSHROOM BODIES OF THE SOLITARY BEE *OSMIA LIGNARIA*

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Bees have evolved to gather pollen and nectar from flowers but for the individual forager to be successful, it must learn the location of food sources within its own environment. In the social honeybee (*Apis mellifera*), the onset of foraging is hormonally-regulated as a component of division of labor. Successful foraging experience has been correlated with an expansion in the neuropil of a brain region associated with navigation and spatial learning called the mushroom body. Here, we ask if similar brain changes occur in *Osmia lignaria,* a solitary bee species where both male and female bees emerge ready to forage. Our analyses will determine if the mushroom body of *O. lignaria* shows structural changes based on foraging experience or aging. Additionally, this study both tests the generality of experience-associated changes in brain structure of honeybees and offers a comparison of this capacity in social vs. solitary species. Preliminary data analyses suggest that foraging experience increases the size of mushroom bodies when compared to newly emerged bees, though changes are not as extensive as those observed in the honeybee.

SIGNIFICANCE OF PETALS AND POLLEN STRUCTURES IN MODULATING BEE VISITATION TO FLOWERS OF WILD ROSES

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Insects use combinations of floral cues to locate flowers and subsequently select which individuals to visit. Flowers of *Rosa* species (Rosaceae), which are nectarless and offer only pollen as a reward, were used as a model for investigating the role of petals and pollen-associated structures in attracting pollinators and eliciting landing and foraging

responses. Behavioral field experiments were conducted on three *Rosa* species, in which newly-opened flowers were altered by removing petals, all or half the stamens, or pollen. The flowers were offered to free-flying insects in two-choice arrays consisting of 5 intact (control) and 5 altered flowers, and responses of insects (mainly bees) recorded. Removal of petals significantly decreased insect attraction, measured by the number of approaches by bees and syrphid flies, and also decreased landing responses. In contrast, removal of all or half of the anthers resulted in significant decreases in approaches by bumble bees only, and in landings by both bumble bees and honey bees, but not by solitary bees or syrphids. Removal of pollen had not impact on bumble bee attraction, but decreased landings to varying extents depending on both the pollen levels and time of day. In concurrent seed set experiments, alteration of petals and anthers had no effect on seed number and weight (maternal function), but their potential impact on pollen export (male function) still needs to be determined. Overall, the findings indicate that petal and pollen-associated traits in *Rosa* flowers provide important cues that modulate flower visitation by bee pollinators, which in turn can exsert strong selective pressures on flower form.

OAK GALL WASP (*DRYOCOSMUS DUBIOSUS*) INSECTICIDAL MANAGEMENT AND IMPACT ON COAST LIVE OAK GROWTH

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Twohorned oak gall wasp (*Dryocosmus dubiosus*) causes marginal leaf necrosis that is sometimes severe on coast live oak (*Quercus agrifolia*). This damage alarms tree owners and prompts management actions, which often are ineffective partly because the cause of damage is frequently misdiagnosed as fungal pathogens or salinity.

We investigated twohorned oak gall wasp control on potted coast live oaks in a UC Davis Arboretum nursery. Oaks received one of four treatments:

1. No gall wasps and no insecticide;
2. Gall wasps (introduced as adults on 24 and 29 March 2003) and no insecticide;
3. Imidacloprid soil drench (8 March 2003) plus gall wasps; or
4. Imidacloprid foliar spray (14 May 2003) plus gall wasps.

Sixty-four potted oaks in an 8×1 complete randomized block design were studied. Leaf galls, foliar necrosis, presence-absence of other insects, and growth of up to 10 shoots per plant were compared until December 2004.

Galls first appeared in late June to early July. Imidacloprid drench prevented leaf galling and necrosis from cynipids. Crown whitefly (*Aleuroplatus coronata*) and woolly oak aphid (*Stegophylla essigi*) that naturally colonized oaks were controlled for 20 months by one drench. Imidacloprid spray reduced galling somewhat, but was less effective than drenching. Foliar spray controlled aphids and whiteflies, but only during the season of application. Caging oaks for 1 week during late March to exclude wasps controlled

aphids for 3 months (until July), apparently because caging coincided with spring migration of alates.

AREAWIDE ORGANIC IPM IN PEAR PRODUCTION

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Areawide management programs for insect pests of apple and pear in the Western US have been successful since their inception a decade ago, targeting codling moth through mating disruption to replace organophosphate insecticides. Pear psylla, another important pear pest, is also appropriate for areawide management, being highly dispersive with potential natural enemies in surrounding habitat. Establishing organic orchards among conventional orchards has been difficult: pests readily migrate from adjacent conventional orchards, yet natural enemy movement is limited by the pesticide barriers. Organic IPM on an areawide basis provides opportunities for immigration of biocontrol agents. In 2002, an Areawide Organic Management Program was established on 310 acres of contiguous pear, surrounded by native vegetation. Organic IPM practices were implemented for insect control throughout the project. However, other organic practices were not required (e.g., 27 nutrient, rodent, and weed management), and approximately 50% of the acreage was Certified Organic. Over three years, there was a reduction in pesticide use and insecticide costs, with no differences in pest densities. However, there have been no correlated increases in natural enemy densities. Fruit yield and quality have been maintained, and alternative marketing programs have been attempted. The success of the program has led to expansion into other areas.

DIAZINON INSECTICIDE: MANAGEMENT PRACTICES FOR PROTECTING SURFACE WATER DURING DORMANT ORCHARD APPLICATIONS, A REGISTRANTS PERSPECTIVE

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Diazinon insecticide has been the standard dormant insecticide program for years to protect orchard crops from numerous overwintering pests. However, periods of heavy rainfall soon after dormant spray applications can potentially transport diazinon off-site to nearby streams and rivers posing a risk to aquatic organisms. Water quality monitoring performed throughout Central Valley waterways after winter storm events has detected diazinon at levels that exceed state standards.

In an effort to protect aquatic species and mitigate offsite movement, diazinon registrants have developed a series of Best Management Practices (BMPs) for use during dormant spray season applications. The practices outlined in this presentation are intended for use in counties and portions of counties located in the Sacramento and San Joaquin valleys below 1000 feet elevation.

In addition to the Best Management Practices discussed, an overview of the Soil and Water Assessment Tool (SWAT) used to develop a pollutant transport model to assess the levels of diazinon in surface waters throughout the Feather River watershed will be presented. Through the use of the SWAT model, potential for reduction of diazinon levels through the implementation of best management practices (BMPs) will be discussed.

UPDATING INTEGRATED PEST MANAGEMENT SYSTEMS FOR PITCH CANKER: KNOWN AND POTENTIAL INSECT VECTORS

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Pitch canker is a disease of pines and other conifers in California that is caused by an exotic fungal pathogen, *Fusarium circinatum*. A number of species of twig, bark and cone beetles (Coleoptera) are known to be vectors of this pathogen. We have initiated a study to refine integrated pest management strategies for pitch canker by determining the relative importance of each of the known insect vectors of *F. circinatum* and to refine integrated pest management strategies for pitch canker by determining the risk that wood infesting insects carry the pathogen. Study sites are located in native Monterey pine stands at Monterey Peninsula, Anõ Nuevo and Cambria. We set up flight intercept traps baited with host volatiles and monitored populations of beetles from April to November in both 2003 and 2004. Our results indicated that bark beetles, primarily *Ips mexicanus* and *Gnathotrichus retusus* (Scolytidae) made up majority of trap catch. *Lasconotus complex* (Coleoptera: Colydiidae) and two species of Cerambycids (Coleoptera), *Asemum nitidum* and *Lepturine insignis* were also abundant. The information obtained from these studies is very important in insect-fungal-plant interactions in forestry, because, to our knowledge, no other study has ever demonstrated the seasonal distribution of fungal pathogens and carried by insects.

ATTRACT-AND-KILL BAIT STATIONS REDUCE CUTWORM NUMBERS IN WASHINGTON CONCORD AND WINE GRAPE VINEYARDS

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Cutworms are the major direct springtime pests in Washington State vineyards. A feeding attractant designed for the Lacanobia fruitworm (by Peter Landolt) also attracts other noctuids such as spotted cutworm (*Xestia c-nigrum* (L.)). The feeding attractant was placed in vials in attract-and-kill bait stations made of insecticide-coated compact discs (CDs). To test their effectiveness in reducing cutworm populations, these bait stations were hung on trellises in both Concord and wine grape vineyards. In early August of 2004, bait stations were deployed in replicated 5-acre plots at density treatments of 0 and 252 stations per plot. Additional plots with shuttlecock bait stations (used in prior studies) were set up to compare shuttlecocks with CDs. CDs are advantageous over shuttlecocks as they are cheaper and more durable. Monitoring of cutworm populations with feeding attractant, pheromone (spotted cutworm), and light traps (the latter two were in control plots only) commenced ten to 13 days before deployment of bait stations and continued post-deployment until December. During the first 12 to 13 days post-deployment, noctuid moth catches in feeding attractant traps were significantly reduced in both Concord and wine grape. At the same time, numbers of spotted cutworms increased in control plot pheromone and light traps in both Concord and wine grape, which indicated peak flight activity shortly after deployment. No significant differences in feeding attractant trap catches were noted between shuttlecock and CD plots. Based on these data, CD bait stations have great potential in Concord and wine grape vineyards for non-chemical reduction of overwintering pest cutworms.

PREDATOR DIVERSITY, HABITAT COMPLEXITY, AND THE STRENGTH OF TERRESTRIAL TROPHIC CASCADES

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The biological control of insect pests is based on the idea that natural-enemy impacts on herbivores will cascade down to positively affect primary producers, resulting in reduced crop damage (i.e. result in a trophic cascade). However, the generality of the occurrence of terrestrial trophic cascades is currently debated. Although trophic cascades have been documented in both agricultural and natural terrestrial systems, the magnitude of the effect appears to be greater in relatively simple agricultural crops as compared to more diverse natural communities, implicating a role for species diversity in mediating their occurrence. Specifically, predator diversity, a combination of species richness and functional-group composition, may mediate herbivore suppression and thus indirectly

impact primary productivity. Increasing predator species richness could promote trophic cascades if species interact additively or hinder cascades if predators are antagonistic. Additionally, the functional-group composition of the predator guild (% intraguild predators) may also influence cascades since strict predators (predators which feed only on herbivores) may have distinctly different impacts on food-web dynamics than intraguild predators. To determine the impacts of predator species richness and functional-group composition on the occurrence of trophic cascades I factorially manipulated both aspects of predator diversity in mesocosms containing *Spartina* cordgrass, *Prokelisia* planthoppers, and a diversity of invertebrate predators (spiders, a coccinellid, and a mirid). From a pool of 3 strict and 3 intraguild predator species, diversity was manipulated by crossing predator richness (1, 2 or 3 species) with functional-group composition (strict predators only, intraguild predators only, or a mixture of strict and intraguild predators). I found that increased predator species diversity diminished the strength of the trophic cascade. Overall, predator species richness had little effect on the herbivore population, however, increasing the richness of strict predators reduced planthopper population size and increased *Spartina* biomass. Alternatively, increasing the proportion of intraguild predators present (changing functional-group composition) diminished planthopper control and dampened cascading effects on plants, both across and within species richness treatments. So I conclude that predator diversity via intraguild predation dampens trophic cascades and decreases plant biomass. Therefore, it might appear that a trade-off exists for conservation biological control such that maximizing predator biodiversity does not necessarily lead to the highest levels of pest suppression and plant biomass. However, further investigation showed that architecturally-complex habitats (i.e. the presence of dead leaf litter) provided a refuge for predators from intraguild predation. Therefore, complex habitats weaken the intensity of negative interactions among predators and promote trophic cascades when predator diversity is high. As a result, agricultural management practices, such as the inclusion of refuges, that aim to minimize the occurrence of intraguild predation in multiple-predator complexes could improve the biocontrol of insect pests and thus increase crop yield via a trophic cascade.

PROJECT MONARCH ALERT - STUDIES OF POPULATION DYNAMICS IN WESTERN NORTH AMERICA

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Monarch Alert is our project name for a series of studies dealing with fall migration, wintering activity, and spring dispersal of monarch butterflies (*Danaus plexippus* L.) in western North America. The studies are carried out at varied spatial and temporal scales. We have employed several approaches including, among others, tagging many individuals, monitoring seasonal populations at 16 focal wintering sites in San Luis

Obispo and Monterey Counties, coordinating and conducting annual Thanksgiving Counts throughout these two counties, characterizing the population genetic structure of the northern half of the western wintering range, and analyzing system-wide population dynamics over a seven year history. The monitoring program has identified probable causative factors that initiate spring dispersal, as well as, local changes in habitat use that often precedes dispersal. One of the preliminary findings of the tagging program is that monarchs transferred almost exclusively to nearby sites and that movement never took place between counties. Finally, the value of multi-scale studies such as these, involving large sample sizes will be illustrated from analyses of seasonal changes in monarch body and wing condition. Two approaches will be contrasted: 1) periodic sampling of the general population and 2) tracking the condition of many tagged individuals over a finite period. Differences between these two approaches can be used to estimate the degree of phenotypic bias in dispersal and facilitate the identification of other abiotic or spatial causative factors that influence dispersal. Quantitative data provided by the Monarch Alert project will help create appropriate conservation strategies that protect this valuable natural resource.

UTILIZING VEGETATIONAL DIVERSITY TO MANIPULATE INSECT POPULATIONS

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Currently, there are many paradigms used to describe agricultural production in the United States, e.g. chemically oriented, conventional, IPM, organic, sustainable, etc but the exact meaning of these terms are no longer really known. Yet, it is reasonable to view the transitions from chemical based agriculture to IPM based management to sustainable or organic methods as different perspectives on the composition of the biological community and how members interact. In its simplest form, chemically intensive agriculture can be viewed as a struggle to eliminate pests, both weeds and herbivorous pests, from the system. Conversely, alternative vegetation (e.g. weeds) can be used as a tool to directly reduce herbivore abundance, indirectly increasing crop biomass (i.e. yield), or attract greater numbers and diversity of natural enemies that will exert a greater controlling force on herbivorous insects. These outcomes are examples of the resource concentration and enemies hypotheses.

How we view biological community on the farm greatly influences the role vegetational diversity plays on the farm. For example, thinking that alternative vegetation acts only directly on either herbivores or natural enemies. These are the easiest interactions to observe and if they were the only interactions, predicting the impacts of vegetation diversity would be straightforward. However, it is possible that alternative vegetation may affect the interaction between two elements of the community, e.g. the rate that predators find and kill prey (Wootton's (1993, 1994) *interaction modification*, a type of

indirect effect) or as a series of direct effects (*interaction chains:* another type of indirect effects).

I set out to explore these questions in the context of the emerging Farmers Market/Community Supported Agriculture (CSA) production system in the Pacific Northwest. This production system is unique in that growers often plant crops representing up to ten different plant families on a single farm. This creates a complex system of vegetation type, pests, and natural enemies. Specifically, I set out to determine if increasing the vegetational diversity associated with production of Brassicaceae crops (e.g broccoli, cabbage) would decrease pest abundance and damage. Analysis focused on aphids (consisting primarily of *Brevicoryne brassicae, Myzus persice* and *Lipaphis erysimi*), flea beetles (*Phyllotreta* sp), and a lepidopteran complex consisting of Imported cabbage worm (*Pieris rapae),* diamondback moth *(Plutella xylostella)* and cabbage looper (*Trichoplusia ni*). Initially, I looked at 17 different crop arrangements on different farms; utilizing their natural variation to look for any crop-pest-predator associations. This survey approach was followed up by two sets of manipulative experiments. The first experiment (1999) manipulated vegetational diversity by passively allowing the background vegetation (e.g weeds) to grow. The second experiment (2000) manipulated two separate background vegetation treatments: a) a clover background (50:50 of *Trifolium repens* and *Trifolium fragiferum*, broadcast seeded at approximately 62.5 lbs/hectare) and b) an arugula background (*Eruca vesicaria subsp. sativa*, direct seeded into 2 rows between each row of broccoli). These two cover crops were seeded into the field approximately one month prior to transplanting broccoli plants.

All experiments were set up in a similar way, using a clean background (no cover crops and hand weeded once every 2 weeks) as the control treatment. Individual broccoli or cabbage plants (broccoli only in 2000) were randomly selected for repeated sampling during the growing season. In addition to recording all observed insects, percent ground cover of both plant and background vegetation and the amount of feeding damage on the plants were recorded. Percent ground cover and damage were assigned to categorical classes of 0 representing no damage or coverage, 1 for 1-10%, 2 for 11-25%, 3 for 26-50% and 4 for greater then 50%. Yield data was taken for only a selected few treatments each year. In addition to yield weight, broccoli heads were given a quality score from 1: no damage, high quality to 4: severely damaged, unmarketable. Each treatment was replicated four times, in 1999 once at each of four farms and in 2000 two complete blocks at each of two farms.

Background vegetation growth varied considerable between farms in 1999. Two farms had relatively low amounts of weed growth compared to the other 2 farms. Lepidopteran abundance did not differ when measured as an aggregate score. Conversely, flea beetle abundance was significantly lower at each farm in the plots where weeds were allowed to grow, ranging from 1/2 to 1/5 the observed abundance in the clean fields. Aphid abundance responded to the background vegetation in a more complex way. The field with the least amount of background vegetation had more aphids in the dirty (weedy) plots when compared to its control (weed free plots). However, the other farms that had higher cover values of weeds had fewer aphids in the dirty plot compared to the control

plots. Harvest data was taken from the two farms with the lowest weed abundance (Jubilee and Rent Due). Each farm showed no reduction in yield weight nor proportion and weight of the highest quality broccoli heads.

There was poor and inconsistent establishment of the clover and arugula cover crops in 2000, making comparisons within and between farms difficult. The sole pattern to emerge from the data was for aphid abundance. Averaged across all plots, broccoli plants with no background vegetation (control plots) had approximately 10 fold more aphids than either cover crop treatment. Plants with a clover background had significantly fewer aphids than plants with an arugula background.

Overall, any amount of background vegetation appears to reduce flea beetle abundance through interfering with the ability of beetles to find the resource patch or losing the resource once they have found it, i.e. reduced immigration rates and increased emigration rates. Conversely, aphid abundance appears to be a complex function of the quantity of background vegetation and the type of vegetation. This result may stem from interfering with natural enemy foraging in the plots with tall weeds or by reducing the ability of the aphids to locate the host plants.

COMPARISON OF THREE CHEMICAL TREATMENTS TO DERTERMINE EFFICACY ON TWO SPIDERS, *TEGENARIA AGRESTIS* AND *LATRODECTUS HESPERUS*

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Pest management professionals (PMPs) are called to eliminate spiders because many homeowners have little tolerance for this large group of organisms. PMPs are faced with the challenge of multiple habitats and the diverse biology of many species. Two spiders of possible medical importance in the Pacific Northwest were chosen for this study: the hobo spider, *Teginaria agrestis*, male and female, and the black widow, *Latrodectus hesperus*, female. Three management strategies were investigated with chemicals applied to the (1) substrate, (2) spider webbing, and (3) directly to the spider. Three classes of chemicals were tested, a synthetic pyrethroid (cyfluthrin), phenyl pyrazole (fipronil) and a neonicotinoid (imidacloprid). Fipronil controlled 96% of the spiders after eights days, cyfluthrin controlled 70% after five days and imidacloprid controlled 18% of the spiders after fourteen days. A higher level of control was obtained with application of fipronil and cyfluthrin to male *T. agrestis* and female *L. hesperus* compared to female *T.agrestis*. Of the three classes of chemicals used in perimeter treatments, these three spider groups were most sensitive to phenyl pyrazole and the synthetic pyrethroid. The spiders were least sensitive to imidacloprid.

SUPPRESSION OF A SUBTERRANEAN TERMITE COMMUNITY USING THE SENTRICON TERMITE COLONY ELIMINATION SYSTEM: A CASE STUDY IN CHATSWORTH, CALIFORNIA

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The RockPointe condominium complex in Chatsworth, CA has had a long history of subterranean termite activity and termite-related homeowner complaints. A total of 7,327 Sentricon stations were installed between October and December of 2001 around 134 buildings, and inspected monthly thereafter. Per label instructions, as termites appeared in the Sentricon stations they were immediately baited with hexaflumuron. When feasible, auxillary stations were installed adjacent to the active stations to enhance the rate of station discovery and bait consumption. Within two months of installation, 41% of the buildings had stations that revealed visual signs of subterranean termite activity and were baited; this percentage rose to 90% after 6 months and 95% after one year. A total of 423 auxillary Sentricon stations were installed between February 2001 and October 2003. Of the 7,327 Sentricon stations initially installed, 12% had subterranean termite activity; 13% of the auxiliary stations became active. The number of newly infested stations plummeted in 2003 apparently due to baiting. Comparing means for newly active stations between 2002 and 2003 resulted in a 70% reduction in new activity. By March 2004, very few newly active Sentricon stations have been recorded. Paralleling the reduction of termites in stations at the site was a reduction in complaints from residents at the complex. These results strongly suggest that the ongoing baiting program utilizing the Sentricon Termite Colony Elimination System has had a significant impact on the subterranean termite community at this site.

MATING AND MATE FINDING BEHAVIOR OF THE NAVEL ORANGEWORM

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Previous studies of *Amyelois transitella*, the navel orangeworm or NOW, mating behavior in small arenas have suggested that the courtship consists purely of a simple behavior sequence. We investigated the mating behavior of NOW in a wind tunnel. A calling female was placed on a stylized branch at the upwind end of the wind tunnel and a

male was then released from the downwind end of the wind tunnel. The male was allowed to fly to and court the calling female. Video recordings were made of the mating sequences and also of the males' flight paths. Transitions between behaviors were recorded from which conditional probabilities were calculated. In the majority of cases when a male made contact with a female, a successful mating ensued. Successful mating sequences were broken down into two categories: 1. Rapid mating – which involved short courtship bouts, under ten seconds, and in which in the majority of cases males approached females from the front and there was head to head contact. In addition there was either limited of no movement by females during the courtship bout. 2. Chase and Mating – which involved long courtship bouts, ranging from 18 to 100 seconds, in which there were extended periods of walking by females and chasing by males. These complex male behaviors may be useful as natural benchmarks for characterizing the reactions evoked by pheromone extracts and synthetic blends.

REFINEMENTS OF INTEGRATED PEST MANAGEMENT STRATEGIES FOR ALFALFA WEEVILS IN CALIFORNIA ALFALFA

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Alfalfa is the number one valued field crop in California with 1 million acres and hay production of nearly $1 billion per year. Several insect pests injure alfalfa plants reducing crop yields and quality. The alfalfa weevil complex, comprised of the Egyptian alfalfa weevil (EAW), *Hypera brunneipennis*, and alfalfa weevil, *Hypera postica*, is the most damaging arthropod in California alfalfa. Weevil larvae are well-controlled with insecticides including organophosphate, carbamate, and pyrethroid materials. However, the occurrence of organophosphate insecticides in surface waters, coinciding with the timing of treatment for EAW larvae, has placed added emphasis on finding alternative means to manage this pest. Pyrethroid insecticides and indoxacarb were recently registered in alfalfa. Alfalfa was one of the more heavily researched crops in the 1970's and 1980's and many IPM principles were developed from studies on alfalfa. However, pest management research efforts in alfalfa have declined during the last 15 years because of competing research/crop priorities, funding limitations, etc. In 2004, we re-evaluated the EAW treatment threshold under current production practices at three locations in the Central Valley and two intermountain locations. These results on treatment threshold and sampling for EAW under the current production regime could facilitate EAW management in California. Preliminary data were collected from one site in 2002 and 2003 and the 2004 studies expanded upon this work.

SEASONAL POPULATION BIOLOGY OF *XYLELLA FASTIDIOSA* AND INSECT VECTORS; IMPLICATIONS FOR SECONDARY SPREAD OF THE ALMOND LEAF SCORCH PATHOGEN

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Almond leaf scorch (ALS) disease has emerged as a serious threat to almond production areas throughout California's San Joaquin Valley and is caused by the xylem-limited bacterium *Xylella fastidiosa* (*Xf*). The bacterium has a diverse host range and is transmitted by xylem feeding sharpshooters (Cicadellidae) and spittlebugs (Cercopidae) in California. Populations of *Xf* were monitored monthly within individual ALS-affected trees in both a Fresno and Kern County orchard through the interval March-November, 2004. Bacterial isolation on solid media, DAS-ELISA, and real-time, PCR based protocols illustrated increasing populations of *Xf* among almond cultivars. Results from insect dispersal studies conducted in 2004 illustrated that adult green sharpshooters (*Draeculacephala minerva*; GSS) and spittlebugs (Cercopidae) were the only potential *Xf* vectors captured dispersing into ALS-affected orchards. Peak dispersal of GSS coincided with peak populations in adjoining acreages of permanent pasture or forage alfalfa. Both GSS and glassy-winged sharpshooter (*Homalodisca coagulata*) transmitted *Xf* at low frequencies to susceptible indictor plants averaging 4.3 and 9.4%, respectively. An accurate knowledge of which vector species transmit ALS strains, where they acquire the pathogen, when they move into orchards, and how they spread the pathogen among susceptible almonds is critical to understanding and managing the spread of this disease.

QUANTITATIVE ANALYSIS OF VOLATILE MONOTERPENES FROM PONDEROSA PINE: IMPLICATIONS FOR BARK BEETLE COLONIZATION AND TREE MORTALITY

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Monoterpenes are naturally occurring plant chemicals that influence the physiology and behavior of insects. For example, myrcene, α-pinene, β-pinene and 3-carene are major components of pine oleoresin. At high concentrations these monoterpenes are toxic to pine bark beetles, but they also serve as attractants for insects such as the western pine

beetle, *Dendroctonus brevicomis*, the red turpentine beetle, *Dendroctonus valens*, or the eastern fivespined ips, *Ips grandicollis* (all Coleoptera: Scolytidae). A GC-FID analysis of extracts of volatiles collected from replicated treatments of chipped or cut *P. ponderosa* trees revealed a striking difference in the quantities of the four monoterpenes emanating from the different treatments. *Pinus ponderosa* chips released 20 to 30-fold more of each monoterpene over most time points during a 36-day collection period. Field studies were conducted in 2003 in the Sierra Nevada in California to compare the effect of chipping or cutting *P. ponderosa* (two techniques for handling forest logging debris) on attack rate by bark beetles and tree survival. Preliminary results in 2004 showed that higher percentages of trees were attacked and killed when the logging debris was left as chips. This result may be related to the higher release of monoterpenes noted above.

HOW AGE STRUCTURE AND WIND INFLUENCE CARPENTERWORM MOTH MONITORING TRAPS IN HYBRID POPLAR TREE PLANTATIONS.

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At Potlatch's hybrid poplar plantation, seven of the ten highest monitoring trap locations for male carpenterworm moths (CW) (*Prionoxystus robiniae*) in 2003 were in fields of two-year old trees. Given CW is thought to primarily attack older trees we sought to test whether high counts in new stands were real or, alternatively, an artifact due to immigrating CW from older, adjacent stands. We tested this hypothesis in 2004 at three study sites, each containing paired new and old aged fields so that the older stands were down wind from the new. In each field 40 traps were placed at an even density of 2.5 traps/ha. Our results indicate males in new stands originated from adjacent older, infested stands. Concurrent to this main study, we monitored female counts at light traps within these fields. The light traps picked up females in both new and old stands, with a much higher total count in the older trees than the new trees (295 to 7, respectively). We tested whether the seven females caught at the light trap could have dispersed the 0.4 km from the older stand to the light trap and determined they could. Our study indicates that 1) high male CW trap counts in new fields may be an artifact thus should be viewed within the context of both age and location, and 2) that while it is unlikely that the moths originated within the stands, this study could not refute this.

CARPENTER ANT MANAGEMENT STRATEGIES USING NEW MANAGEMENT TOOLS AND APPLICATION TECHNIQUES

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Carpenter ants are major structural pests in the United States. With the advent of non repellent chemicals and more attractive baits, shifts have occurred in management strategies that include perimeter sprays and baiting as the sole method of control. In the Pacific Northwest, management strategies concentrate on the following species: *Camponotus modoc, C. vicinus, C. herculeanus,* and *C. essigi.*

Baiting as a single strategy is a successful carpenter ant management tool. Attraction and recruitment of foragers plus the transfer of bait to other colony members are recognized as important parameters in the development of a successful bait. Fipronil in a gel bait formulation was transferred from the initially exposed colony through two transfers to small colonies established in the laboratory. There was a 95% mortality in the initial colony, 57% mortality after the first transfer, and 46% mortality after the second transfer.

Two studies involved perimeter sprays as the sole method of control. In a comparison of bifenthrin, fipronil, and cyfluthrin, all three chemicals were effective in managing the ant populations. Another study compared power spraying at high volumes and reduced volume applied with a compressed air hand sprayer. Control with a power sprayer was achieved at 43% of the structures compared to 80% control at structures treated with a compressed air hand sprayer, indicating the importance of chemical placement.

VISUAL AND OLFACTORY STIMULI IN HOST-PLANT IDENTIFICATION BY THE OLIGOLECTIC BEE *CHELOSTOMA FULIGINOSUM* (MEGACHILIDAE)

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Chelostoma fuliginosum bees are narrowly oligolectic, foraging exclusively on the genus *Campanula* (bellflowers). Due to their short life span and univoltine reproduction, they must emerge from the nest with a defined search image that will allow them to identify their host plant in the field, and this search image may change as they become foraging-experienced. Multiple-choice behavioral tests were conducted to determine the role of visual and olfactory floral cues in flower recognition in both foraging-naïve and foraging-experienced bees. Female bees, tested individually, were offered a choice of 1) whole flowers of six species, 2) whole flower odors of four species, 3) odors of different flower parts of *C. trachelium*, and 4) six different colors; bee responses (landings and feeding attempts) to each sample were recorded. The findings indicate that both foraging-naïve and foraging-experienced bees 1) immediately identified their host plant when presented

with different whole flowers, but 2) did not show any clear preference when offered only whole-flower odors and 3) were most attracted to the color yellow even though their host flowers are blue. In addition, foraging-experienced bees demonstrated a significant preference for odors of the nectaries over the flower petals, and future tests will be conducted with foraging-naïve bees. Overall, use of visual and olfactory floral cues in host-plant recognition by *C. fuliginosum* is unclear, but stimuli from the nectaries and pollen might play a key role in guiding bees just prior to landing on a flower.

TEPHRITID FRUIT FLY SURVEY IN HAWAII: YIELD NEW CLUES OF ECOLOGICAL EFFECTS

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Tephritid fruit flies consisting of the Mediterranean fruit fly, the Melon fly, the oriental fruit fly, and the Solanaceous fruit fly are perennial pests of vegetable and fruit crops in Hawaii. The complex ecosystem in Hawaii is an ideal environment where these fruit flies persist causing serious damage to vegetable and fruit crops and increasing the cost of trade from mandatory quarantine treatment of export commodities. To help increase the benefit growers receive from area wide pest management of fruit flies, the USDA's Agriculture Research Service conducted tephritid fruit fly surveys in urban and agricultural areas with special attention to those locations where the urban and farming enviromments overlap. The goals of the program are: 1) develop information on the ecology of tephritid fruit fly and parasitoid females 2) Determine which fruit fly species does the most damage to fruit and vegetable crops in the urban environment. 3) Determine the host plants the tephritid fruit flies use to share larval food resources in the same and different habitats. The tephritid fruit flies were introduced into Hawaii at different times but that does not appear to influence their current distribution. The sampling tools being used for fruit fly survey include protein bait traps, male lure traps, fruit traps, fruit sampling, random and stratified sampling with the sampling tools. The results from the use of the sampling tools will be discussed with regard to their relative efficiency including ecological effects.. In conclusion , the application of the trap survey information for improving the Area-wide IPM Program will be discussed.

ASSESSING THE USE OF NATIVE BEES AS BIOLOGICAL INDICATORS IN A RIPARIAN HABITAT

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This study investigated the efficacy of using native bees as biological indicators in riparian ecosystems. I measured the abundance and diversity of native bee populations at 10 sites along Putah Creek (Yolo and Solano Counties) from May 2004 to October 2004, to determine if these parameters varied with disturbance level. I sampled the bee populations using pan traps and aerial netting; the specimens were identified and categorized by family and subfamily. The level of disturbance at each site was categorized as low, medium, or high based on width of the floodplain, ratio of native to non-native herbaceous plants in the floodplain, and width of riparian forest. Abundance and diversity of native bees were positively correlated with a high ratio of native to non-native plants. Sites with an intact floodplain had a higher ratio of native plants and consequently supported a higher abundance of bees. The abundance of native bees was lower in May and June than in September and October indicating that bee populations responded to seasonality. A secondary component of this study was the evaluation of commonly used pan trapping methods. Bees from the family Halictidae were over represented in blue pan traps. The preliminary data from this study indicated that native bees may be useful for evaluating the floodplain plant community and provided evidence that there is a need to refine pan trapping techniques. However, effective use of native bees cannot be achieved until patterns of population/species response to seasonality, disturbance, and trapping methods are elucidated.

MAKING A BEE-FRIENDLY GARDEN

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Two seasons of work with habitat manipulation, beginning in the fall of 2003, allowed us to determine which native and exotic plant species best attract native Californian bees. From this we developed a detailed outline and overview of how to create habitat to promote the visitation and permanent residence of native California bees in small garden plots situated in urban areas. Consideration was given to the seasonal changes in floral and faunal interactions, as well as to the individual bee species and their most attractive plants. This study will continue into 2005 and will examine nesting and mating habitats more closely. The project objective is to develop a guide to "gardening for bees" that will provide native California species with complete habitat resource availability for feeding, mating, and nesting.

PROGRESS AND STATUS OF MATING DISRUPTION FOR THE CONTROL OF NAVEL ORANGEWORM IN ALMONDS AND PISTACHIOS

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The navel orangeworm (*Amyelois transitella*) is the major orchard pest of almonds and pistachios in California. Aerosol dispensers ("Puffers") and membrane dispensers (Suterra) containing (*Z,Z*)-11,13-hexadecadienal, the major component of the navel orangeworm (NOW) sex pheromone, were evaluated for disruption of mating and damage reduction in almond and pistachio orchards during 2002, 2003 and 2004. Puffers (2 per ac) deployed in grids and perimeters around 16 ha (40 ac) and 8 ha (20 ac) test plots, membrane dispensers (almond only, 150/ac) and conventional insecticide programs were compared to untreated control plots in multiple 256 ha (640 ac) sites. We found that NOW adults occurred in much greater numbers in pistachio compared to almond from early March until August, when relative numbers of moths in almond approached levels found in pistachio. The mating disruption technologies had pronounced biological impact in both crops, reducing males captured in virgin female-baited flight traps by 94-99% and the number of females mated in assays by ~80-90%. In addition, trap captures in virgin baited traps placed outside of mating disruption plots but within the study sites were suppressed relative to traps 400 meters upwind. In all pistachio sites, the proportion of nuts damaged by NOW was not significantly different in blocks receiving mating disruption treatments compared to untreated control plots. This was a distinct contrast with almonds, in which the range of damage was much greater, and the mating disruption treatments had significantly less damage than untreated controls. Increasing abundance of navel orangeworm had a more direct effect on damage in almonds compared to pistachios as indicated by correlations of trap counts and damage. Comparison of membrane dispensers, puffers placed peripherally and puffers gridded throughout plots suggested that the gridded aerosol dispensers were most effective in reducing males captured in female-baited flight traps and females mated in assays, and showed that this was the most effective of the mating disruption treatments for reducing navel orangeworm damage in almonds. The results of our studies suggest that almonds offer the best opportunity for effective use of mating disruption against the navel orangeworm at this time.

ROLE OF STATE RESOURCES IN PERFORMING TESTING, STANDARDIZING RESULTS AND COLLATING DATA REGIONALLY

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The California Department of Health Services (DHS) oversees the statewide surveillance program for West Nile virus and other arboviruses. DHS, in collaboration with other

agencies, conducts arbovirus surveillance in humans, equids, sentinel chicken flocks, mosquitoes, and wild birds. The DHS Viral and Rickettsial Disease Laboratory provides testing for suspect human cases and sentinel chickens. The University of California, Davis, Center for Vectorborne Diseases conducts virus isolations from mosquitoes. The California Department of Food and Agriculture coordinates surveillance in equids. The DHS Vector Borne Disease Section in Richmond maintains the system for reporting and testing dead wild birds.

DHS collates and disseminates data from each of the surveillance activities to public health agencies, vector control districts, and other interested parties. Adult mosquito collection counts are presented in the Adult Mosquito Occurrence Report. Human cases are reported twice weekly and equine cases weekly. Results of the dead bird surveillance program are distributed weekly. DHS publishes a summary of surveillance activities each week in the California Arbovirus Surveillance Bulletin. All issues of the California Arbovirus Surveillance Bulletin are available at the California West Nile virus website: www.westnile.ca.gov.

Through timely collection and synthesis of surveillance data, DHS enables local agencies to make informed response decisions to the rapidly changing dynamics of arbovirus transmission.

PEST MANAGEMENT PRACTICES IN FOOD PROCESSING

Ed Hosoda

Cardinal Professional Products

Pest management in food processing facilities utilize the concept of "Integrated Pest Management" by implementing a multi-faceted approach to minimize pest populations. First and foremost, paying strict attention to sanitation both inside and outside the facility will minimize the necessity for pesticide applications. Monitoring for specific pests by initiating regular and thorough inspections, using pheromone traps, insect light traps and other methods will alert management of potential pest problems that may need to be addressed immediately. Once a specific pest is identified, a control method can be determined. Insect and rodent pests may require minimal applications of pesticides to achieve control. If the population reaches a certain threshold, other control methods may be necessary, such as broad applications of insecticides, or perhaps the use of fumigants to eradicate the pests. New, more bio-rational pesticides are available, which reduce the potential for food contamination, worker exposure, yet provide excellent control of unwanted pests.

A HISTOLOGICAL DESCRIPTION OF THE REPRODUCTIVE SYSTEM AND SEASONAL REPRODUCTIVE ACTIVITY OF FEMALE HOMALODISCA COAGULATA (SAY) IN SOUTHERN CALIFORNIA

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Female *Homalodisca coagulata* (Say) have been collected from October 2001 to January 2005 at monthly or bimonthly intervals from citrus hosts at UC Riverside Agricultural Operations. A sub-sample of 10 females per sample date was dissected to determine ovary rank of the specimens collected. Ovary rank is assigned based on a set of morphological characteristics of the ovarioles. Dissections of these female specimens reveal repeated patterns related to the proportion of previtellogenic females in the field. These patterns indicate two distinct generations each year with a possible third generation late in the season. In addition to dissections, a subset of specimens in each ovariole rank was examined histologically to verify the dissection data. The ovarioles are of the telotrophic type which is typical of Cicadellidae. We have developed a model of *H. coagulata* vitellogenesis cycles in Southern California which can be used to predict timing of reproductive events. This detailed knowledge of reproductive activity of *H. coagulata* can be applied to improve timing of suppression and eradication control efforts in Southern California.

CHALLENGES IN DEVELOPING A POST HARVEST FUMIGANT

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DFA of California is a non-profit agricultural association of dried fruit and tree nut processors whose members produce over 75% of these commodities in California. The association began in 1908 and has a fully equipped analytical laboratory located in Fresno California that conducts analyses for shipping commodities as well as research, including bacterial pathogen studies, storage condition, pesticide residues and post harvest fumigation. Methyl Bromide has been used successfully for post harvest fumigation, but due to the Montréal Protocol, its use has decreased. DFA has been working with a number of fumigants in the last decade to replace this successful crop protection product. A number of post harvest insects including indian meal moth *Plodia interpunctella,* red flour beetle *Tribolium castanium,* and warehouse beetle *Trogoderma variable* will be compared and contrasted. Egg, larvae, pupa and adult stages require varying doses to achieve an efficacious dosage. Lower temperatures often require either a greater dosage or longer fumigation time. The regulatory challenges and the development costs prohibit new fumigants.

INSECTICIDES WITH NOVEL MODES OF ACTION – AN OVERVIEW

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Efforts have been made during the past three decades to develop novel insecticides with selective properties to act on biochemical sites or physiological processes present in a special insect group but differ from others in their properties. This approach has led to the formation of compounds, which affect the hormonal regulation of molting and developmental processes in insects such as ecdysone agonists (tebufenozide and methoxyfenozide), juvenile hormone mimics (pyriproxyfen and fenoxycarb), and chitin synthesis inhibitors (benzoylphenyl urea's and buprofezin). In addition, compounds which inhibit or enhance the activity of biochemical sites, such as respiration (diafenthiuron), or interact with nicotine acetylcholine receptors (neonicotinoids), have been introduced for the control of aphids, whiteflies and a diversity of other insect pests. Compounds originating from natural products (avermectins and spinosad), which act on specific biochemical sites, such as GABA and glutamate receptors and chloride channels, have been developed and used successfully to combat mites, thrips, and other agricultural pests. *Bacillus thuringiensis* δ-endotoxin, which affects the mid-gut ion exchange, has been developed as an insecticide to control lepidopteran pests or introduced as a component in transgenic field crops aiming at suppressing important agricultural insect pests. We will present an overview relating to mechanism, selectivity and importance of novel insecticides in pest management programs.

NOVALURON, A NOVEL BENZOYLPHENYL UREA, MECHANISM, SELECTIVITY AND IMPORTANCE IN PEST MANAGEMENT PROGRAMS

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Novaluron (Rimon), 1-[chloro-4(1,1,2-trifluoro-methoxyethoxy)phenyl]-3-(2,6-difluorobenzoyl)urea, a novel benzoylphenyl urea acts by both ingestion and contact. It is a powerful suppressor of lepidopteran larvae such as *Spodoptera littoralis* and *Helicoverpa armigera* (by ingestion) and whiteflies such as *Bemisia tabaci* (by contact). This compound has translaminar activity thereby affecting leaf miners such as *Liriomyza huidobrensis.* Its residual activity, under field conditions, ranges between 10 and 30 days

depending on environmental conditions. Artificial rain, at a rate of 40 mm/h applied 5 and 24 h after novaluron treatment in a cotton field had no appreciable effect on the potency of novaluron on *S. littoralis* larvae. Novaluron has no appreciable cross-resistance with the juvenile hormone mimic pyriproxyfen or with the neonicotinoids acetamiprid and thiamethoxam. Hence these compounds can be used as components in insecticide resistant management for controlling whiteflies and other insect pests in cotton and field crops. Novaluron has no appreciable effect on parasitoids and phytoseiid mites, and probably has a mild effect on other natural enemies. Hence, it can be considered an important component in integrated pest management programs.

FINDING A ROLE FOR BOTANICAL INSECTICIDES IN AGRICULTURAL PEST MANAGEMENT

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Botanical insecticides, largely displaced by synthetic insecticides in the latter half of the 20th century, have recently been touted as useful tools for integrated pest management in agricultural and urban contexts, particularly in the context of the Food Quality Protection Act. Two long-established botanical insecticides, pyrethrum and rotenone, remain in use, while other botanicals (ryania, sabadilla) are little used today. Rotenone is also losing favor in most markets, but retains its major use as a fish poison. The traditional products have been joined by two newer botanicals; neem in the early 1990s, and plant essential oils in the past five years. Pyrethrins (in pyrethrum) and monoterpenoids (in essential oils) are broad-spectrum contact insecticides, with fast knockdown properties. Azadirachtin (from neem) differs from these in being an insect growth regulator (ecdysone antagonist) and antifeedant. In general terms all of these botanicals are relatively safe to the user, the consumer, and the environment, but their limited persistence under field conditions often necessitates repeated and high-volume applications. Regarding their compatibility in IPM programs, natural enemies and pollinators are often susceptible to poisoning by pyrethrum, essential oils and to a lesser extent, neem, although the short half-lives of these insecticides in the field can minimize perturbation of natural enemy populations. In conventional agriculture, botanicals tend to be relatively expensive and face stiff competition from synthetic insecticides or other biologically-based pesticides with greater efficacy and persistence. The most important role for botanicals is in organic food production systems where growers have fewer tools available for pest management. Botanicals will also find adoption and utility in some other agricultural niche markets (e.g. fly control in dairy barns) in addition to urban contexts where there is a heavy premium placed on protection of human health and the environment.

USING THE CHEMICAL LANGUAGE OF PLANTS TO IMPROVE CONSERVATION BIOLOGICAL CONTROL IN CROP PROTECTION

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Plants communicate with each other and with arthropods using an array of chemical signals. Some of the most functionally important of these are herbivore-induced plant volatiles (HIPV) used by plants in direct and indirect defense. Synthetic versions of some of these volatiles have recently been shown to be potent field attractants for a number of predatory insects. Vineyards and hop yards baited with methyl salicylate (a common component of many HIPV blends) recruit and maintain larger populations of a wide variety of beneficial insects, than unbaited crops. In some instances improved biological control of spider mites and aphids has been demonstrated. Mechanisms contributing to synthetic HIPV-mediated enhancement of beneficial insect populations remain to be elucidated but are suggested to consist of both direct and indirect (via plant-signaling) attraction.

MONITORING FOR ORGANOPHOSPHATE INSECTICIDES IN THE HOOD RIVER BASIN, OREGON

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The Hood River basin is a major tree fruit production region of Oregon. As a result of detections of the organophosphate insecticides chlorpyrifos and azinphos-methyl in tributaries of the Hood River at concentrations that exceed water quality standards, a four year monitoring program was initiated in conjunction with efforts to encourage the adoption of pesticide best management practices (BMPs) designed to reduce stream loading. This community-based effort included the Oregon State University Mid-Columbia Agricultural Research and Extension Center, the Hood River Grower-Shipper Association, the Hood River Soil and Water Conservation District, the Hood River Watershed Group, the Confederated Tribes of Warm Springs, the Oregon Department of Environmental Quality, and the Oregon Department of Agriculture. This study complemented the EPA-funded Best Management Practices Project to reduce broad-spectrum pesticides, especially OPs in surface water of the Hood River Valley and improve water quality (see symposium on ‘Pesticides and Water Quality’).

SULFUR DISRUPTION OF HOST-PARASITOID INTERACTIONS IN THE VINEYARD AGROECOSYSTEM

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Agricultural practices can interrupt naturally occurring interactions among hosts and parasitoids. In vineyards, management practices can disrupt natural enemy biology and inhibit the biological control of insect pest populations. The egg parasitoid *Anagrus erythronurae* is both a common and abundant natural enemy in California vineyards, yet it has not succeeded in preventing its leafhopper host, *Erythroneura elegantula*, from becoming an agricultural pest. Sufficient biological control of the grape leafhopper can be expected because high rates of parasitism by *Anagrus* parasitoids are often seen late in the growing season. We studied whether the use of sulfur in vineyards is responsible for the lack of sufficient pest population regulation by the *Anagrus* parasitoid. Sulfur is a broad spectrum fungicide used in the vast majority of organic and conventional vineyards to control powdery mildew. Using an observational experiment we compared *Anagrus* parasitoids in vineyards that used sulfur to those in vineyards that did not use sulfur. We measured female oviposition success and found that parasitoids in sulfur vineyards laid fewer eggs in leafhopper hosts than parasitoids in non-sulfur vineyards. Further manipulative field experiments test whether the removal of sulfur from the vineyard agroecosystem restores biological control of the grape leafhopper by the *Anagrus* parasitoid. This work attempts to elucidate how current vineyard management practices can disrupt natural enemy biology and how alternative practices may facilitate biological control.

VACUUM TREATMENTS FOR POSTHARVEST DRIED FRUITS AND NUTS

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California produces nearly all of the walnuts, almonds, and pistachios grown in the United States, resulting in an annual production of about 700,000 metric tons of commodity valued at more than $1 billion. A large portion of California tree nuts (more than 400,000 metric tons) are sold for the export market. A major problem in the storage and marketing of California tree nuts is infestation by a variety of postharvest insect pests, including field pests of possible phytosanitary importance such as navel orangeworm, *Amyelois transitella*, and codling moth, *Cydia pomonella*, as well as common stored-product pests such as Indianmeal moth, *Plodia interpunctella*, and red flour beetle, *Tribolium castaneum*. Currently, the dried fruit and tree nut industry relies on fumigation with methyl bromide and phosphine for postharvest insect control. Increasingly restrictive regulatory actions, as well as insect resistance to hydrogen phosphide, may make these fumigants costly or unavailable to the nut industry. In

addition, as the organic industry expands, the need for nonchemical postharvest insect control methods increases. Vacuum treatments have been considered as alternatives, but required expensive vacuum chambers to obtain the low pressures needed. Recently, inexpensive vacuum treatments were made possible by treating product in flexible, portable containers, originally designed to fumigate product. We are evaluating vacuum treatments for control of postharvest dried fruit and nut pests.

Because vacuum treatments produce low oxygen atmospheres, these treatments are very similar to controlled atmosphere treatments. Consequently, they are highly temperature dependent, and the exposure times needed for complete control decrease as temperatures increase. However, vacuum treatments also cause dehydration in treated insects, and exposure times needed for vacuum treatments may be shorter than for low oxygen treatments. Our laboratory studies have shown that the presence of commodity may affect treatment efficacy by influencing dehydration of the treated insects. In most previous studies, the egg stage has proven to be the most tolerant to vacuum treatment. We found that diapausing larvae of the Indianmeal moth and codling moth are similar to the egg stage in their tolerance to vacuum treatments. At 25°C, vacuum levels of 50 mm Hg resulted in complete control of all stages after 72 hours of exposures. At 30°C, very high levels of mortality (>99%) of all stages were obtained after 24 hours of exposure to the same vacuum level. Although there are some difficulties in treating dried fruits and product in field bins, vacuum treatments may prove to be a useful alternative for bagged almonds, walnuts and pistachios.

IMPACT OF LEGALLY COMPIANT ORGANIC PESTICIDES ON NATURAL ENEMIES

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Twenty-nine studies were reviewed that examined the impacts of four commercially produced insect pathogens, spinosad®, and neem / azadirachtin on 49 natural enemy species among 23 arthopod families (including insects, mites, and spiders). Results indicated that many toxins used in legally compliant organic pesticides have the ability to either kill or debilitate (via sublethal effects) many parasitoids and predators commonly found in agriculture. These results are mainly based on laboratory experiments with few studies conducted in the field. Greater than 20% mortality was caused to most species (42 of 49) by the compounds / pathogens examined. *Hippodamia convergens* and *Podisus maculiventris* were the only species tested in all three toxin categories without > 20% mortality, but the latter species did exhibit sublethal effects following neem / azadirachtin exposure.

The insect pathogens appeared to be the safer controls, however, there was much less data in this category. Spinosad appeared to be the greatest threat to the parasitoids. The predators were similarly impacted by spinosad and neem / azadirachtin. Most of the data

discussed originated from laboratory studies. We found no reported examples of actual pest resurgences or secondary pest upsets due to the destruction of natural enemy populations by applications of these compounds. The true impact of these compounds must be viewed in these terms. More field-oriented research is needed to determine if these disruptions are actually happening in organic crops.

REPRODUCTIVE MORPHOLOGY AND GENETIC-BASED RECOGNITION OF A NON-NATIVE INVASIVE BARK BEETLE, *SCOLYTUS SCHEVYREWI*

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A new exotic scolytid, *Scolytus schevyrewi,* Semenov (Coleoptera: Curculionidae) banded elm bark beetle was identified for the first time in 2003 in the United States. This new species is morphologically similar in general size, shape, color, and specifically in the size, shape and location of the distinguishing apical spine to the previously introduced species, *Scolytus multistriatus* Marsham, smaller European elm bark beetle, and also to a native species, *Scolytus picea* (Swaine), spruce engraver. Identifying a non-native from a resident or native without prior knowledge of morphological characters can be difficult when the species are similar and even more difficult when the hosts are the same. Reliance on adult external morphology characters can be problematic; degree of variability, lack of quality specimens, and the need to identify developmental stages can hamper early detection programs. *S. schevyrewi* was actually found in the southwest in 1998 but was not identified until April of 2003 from collections from Utah. In this study I use other morphological and genetic techniques, including reproductive morphology (seminal rods), cytogenetics (karyology), and molecular genetics (RAPD-PRC) to characterize *S. schevyrewi*, and to distinguish it from *S. multistriatus* and *S. picea.*

CORRELATIONS OF GLASSY-WINGED SHARPSHOOTER PROBING BEHAVIOR WITH AC ELECTRICAL PENETRATION GRAPH (EPG) WAVEFORMS USING VIDEO AND ARTIFICIAL DIETS

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Glassy-winged sharpshooter (GWSS), Homalodisca coagulate (Say), is the main vector of Xylella fastidiosa, the casual bacterium of Pierce's Disease in grapevine. A detailed understanding of GWSS probing behavior is important because X. fastidiosa is acquired and inoculated when GWSS feeds. To further elucidate GWSS probing behavior we used

the AC electrical penetration graph technique (AC EPG) and video to correlate GWSS probing behaviors with EPG waveforms in artificial diets. Three previously described waveforms, A1, B1 and B2, were correlated with GWSS stylet activity. Fascicle protraction, alternating mandible retraction and maxillary tip fluttering were correlated with subdivisions of the A1 waveform. Salivary sheath formation was also observed in A1. Waveform B1 was correlated to maxillary fluttering within the salivary sheath. Termination of the B1 waveform and maxillary fluttering would sometimes occur when the maxillae were inside the saliva sheath and always when the maxillae exited the salivary sheath. Waveform B2 was associated with stylet path branching within the salivary sheath. During B2, GWSS would "saw" a new stylet branch in the salivary sheath by rapidly retracting and protracting its stylet fascicle in a skewed direction from the original branch. Termination of B2 occurred when the stylets "sawed" through the salivary sheath.

INSECT ECOLOGY ON BAHAMIAN ISLANDS AND A POTENTIAL CANCER CURE

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Borrichia arborescens (L.) DC. (Compositae: Heliantheae) is a coastal perennial occurring on small islands located off the coast of Great Exuma, Bahamas. *Pitnus huesanus* Fisher (Coleoptera: Anobiidae) is a small, approximately 1.3 mm in length, flightless beetle that uses *B. arborescens* as a host plant. While investigating the feeding niche of *P. huesanus,* and working on seed extraction from *B. arborescens,* seed predation was evident in *B. arborescens* by unidentified larvae of Lepidoptera, Diptera and Coleoptera, however, field observations revealed little to no predation on leaves. When confined with *B. arborescens* leaves, adults of *P. huesanus* exhibited surface leaf grazing that resulted in minor surface discoloration where adult beetles grazed. Little is known about the biology of *Pitnus spp.* Initial field observations found no leaf mining by *P. huesanus* on *B. arborescens.* The absence of significant predation suggests a natural plant compound acting as an insect deterrent. Previous work on *B. arborescens* revealed chromatogram patterns, from leaf extracts, of unknown flavonoid compounds similar to those of hymenoxins and nevadensins. Flavonoids display anti-carcinogenic, anti-inflammatory, antioxidant and anti-allergenic properties. Local “bush doctors” use *B. arborescens* boiled as a tea for ailments including coughs, colds and fish poisoning or nerve damage. Biochemical analyses on plant tissue are under way to determine the structure of any flavonoid or terpenoid compounds present. Analyses of variance in flavonoid compound structure between plants on islands of varying distances from the mainland will also be investigated to determine any correlation with effects of isolation and plant fitness.

THE BIOLOGY AND BIOLOGICAL CONTROL OF THE NETTLE CATERPILLAR, *DARNA PALLIVITTA* (MOORE), IN HAWAII

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The nettle caterpillar, *Darna pallivitta* (Moore) (Lepidoptera: Limacodidae) is an invasive species that was discovered on the Big Island of Hawaii in September of 2001. *D. pallivitta* quickly became established despite eradication efforts by the local nurserymen and is now considered a pest of quarantine and health concern since *D. pallivitta* feeds on a wide variety of foliage plants and possesses a painful sting. Field surveys of adult and larval populations were conducted as well as sentinel egg surveys and larval field collections to identify any natural biotic mortality factors. Light trapping and field surveys found at least three generations of *D. pallivitta* occurring each year with high population density during the summer months and early fall. Surveys of host plants of eight to twenty feet in height indicated 85% of *D. pallivitta* larvae were found less than three feet from the ground. Larval field collections and sentinel egg surveys yielded three natural biotic mortality factors – *Trichogramma papilionis*, an unidentified tachinid, and a cytoplasmic polyhedrosis virus. The results of this work may prove useful for both management efforts of *D. pallivitta* and quarantine inspection of export foliage plants.

THE RIGHT TIMING AND ENOUGH PHEROMONE: MATING DISRUPTION IN HYBRID POPLARS

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In 2003 we received a regional section 18 for the use of an unregistered sex pheromone for use against the Western Poplar Clearwing Moth. There were two factors that prevented the optimal effectiveness of our mating disruption strategy: 1) The section 18 was not given to us until May 29th in 2003, a month and a half after the first emergence of WPCM. 2) We were limited by the amount of pheromone supplied. We believe that the majority of the damage that occurred in 2003 was due to the late application of pheromone. In 2004 we received our section 18 and had the pheromone applied before the first emergence of the WPCM. By applying pheromone on time, we reduced the mean number of hits at the base of 1st year trees from 0.30 hits/tree to 0.12 hits/tree, and eliminated the need for a third replant.

We were limited to 11kg of pheromone in 2003. This limitation allowed us only enough pheromone for the 1st and 2nd year trees, leaving almost 25,000 acres untreated and a very large population of WPCM to mate and immigrate to the adjacent younger trees. Without the pheromone limitation in 2004, we were able to treat 25,000 acres of poplars, which we believe along with the proper timing of applications, reduced the mean amount of damage from 0.45 hits/tree in 2003 to 0.24 hits/tree in 2004.

APPLICATORS, IRRIGATORS AND REGULATORS: BALANCING PEST MANAGEMENT NEEDS AND WATER QUALITY

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Detections of farm inputs, especially crop protection chemicals, in surface waters throughout California have prompted adoption of regulatory programs to address the impact of this runoff on waters of the state. The users of farm inputs and the production experts they rely on are faced with the challenge of balancing pest management realities with regulator's needs to respond to public pressure to do something. The regulatory approaches taken to solve these problems have potential to impact how pests are managed across vast areas of the state, some where impacts to surface water quality are remote or non existent. Can regulations be fine-tuned to respond to the current or potential environmental impacts without strapping all of production agriculture with wasteful or unneeded regulations and added costs which have negligible impact on improving water quality?

RE-EXAMINATION OF SYNTHETIC ATTRACTANTS FOR NAVEL ORANGEWORM ADULTS

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Initial reports on synthetic attractants for Navel Orangeworm (NOW) adults indicated nearly exclusive female trap capture. We found that both male and female moths were trapped and that nearly all females were mated, as evidenced by the presence of a spermatophore(s) in their bursa copulatrix. The sex ratio varied during the testing period. During some trapping periods, the number of NOW adults trapped with the attractants was close to the number of males trapped in unmated (NOW) female-baited traps; however, the ratio of adults trapped in these two trap types was not consistent. The possible field use of one or more of these compounds for monitoring NOW during a mating disruption program will be discussed.

RANGELAND GRASSHOPPER TREATMENTS USING ULTRA-LOW INSECTICIDE COVERAGES AND KAIROMONAL ATTRACTANTS

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Reduced Agent and Area Treatments (RAATs) is a strategy of integrated pest management (IPM) of rangeland grasshoppers in which the rate of insecticide is reduced from traditional levels, and untreated swaths (refuges) are alternated with treated swaths. Ground application of RAATs with a sprayer mounted on a heavy-duty all-terrain vehicle (ATV) was implemented on replicated, 20-acre plots of northern mixed-grass prairie in SE Wyoming. The insecticide used was an insect growth regulator diflubenzuron (Dimilin® 2L) at a dose rate of 1 oz. of a.i. per acre. Pre-treatment grasshopper densities ranged from 17.5 to 33.5 individuals per m^2. Grasshopper communities were dominated by second and third instar nymphs of *Aulocara elliotti, Ageneotettix deorum* and *Melanoplus spp.* Insecticide was applied in 20-ft swaths as 50, 33 and 20% coverage. Fifty percent coverage yielded 83% of corrected mortality 21 d after application. Thirty-three percent coverage resulted in 78% of corrected mortality, while twenty percent coverage yielded 62% of corrected mortality 21 d post-treatment. Taking into account the costs of the insecticide and labor, the 33% coverage appeared to generate the best compromise for sufficient control and acceptable cost of the operation.

In order to enhance the insecticide formulation, two different rates of kairomonal attractants (mineral and vegetable oils) were added to Dimilin® 2L. The insecticide was applied at a dose rate of 1 oz. of a.i. per ha in a 33% coverage. The adjuvant combinations included 1) 8 oz/ac of crop oil concentrate, and 2) 2 oz/ac of crop oil concentrate and 6 oz/ac of canola oil. Without adjuvants (with only water added), Dimilin® 2L application yielded 69% control 21 d post-treatment. Addition of crop oil concentrate increased the control to 83%, and a combination of canola oil and crop oil concentrate resulted in the highest 89% control 21 d after application. Attractant and phagostimulant properties of oils allow to enhance the effectiveness of the insecticide formulation and ensure the adequate protection from pest grasshoppers.

SYMBIOTIC CONTROL OF PIERCE'S DISEASE: BEYOND INSECT-MICROBE INTERACTIONS

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The use of endosymbionts to manage pathogen transmission is known as Symbiotic Control. Symbiotic Control takes advantage of the natural presence, competitive attributes, and fitness advantages of endosymbionts in ways that make the establishment and/or successful invasion of pathogens unlikely. While numerous accounts exist that describe interactions between insects and microorganisms, such as parasitism and fitness costs, few reports describe how naturally occurring interactions can be manipulated further to control pathogen transmission and manage plant and animal diseases. *Alcaligenes xylosoxidans denitrificans* (Axd) has been identified as a Symbiotic Control candidate used for control of Pierce's disease (PD). Here we report on the "behavior" of a strain of Axd that expresses a short chain antibody specific to a grape strain of *Xylella fastidiosa,* the causal agent of PD. The strain was introduced to natural environments, such as soil, water, plant surfaces, and to insects. All data collectively suggest that the manipulated Axd shows potential for delivery of an anti-*Xylella* product with little impact on nontarget bacterial ecosystems. This statement is qualified by the fact that field tests must be implemented to assess the true behavior of strains of Axd in the environment. Laboratory studies are not suitable for a genuine assessment of risk assessment and environmental impact; nevertheless, they provide important insight.

REVERSE CHEMICAL ECOLOGY: NOVEL MOLECULAR-BASED APPROACH FOR IDENTIFICATION OF NOW PHEROMONE SYSTEM

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We have isolated, cloned, and developed expression systems for odorant- and pheromone-binding proteins identified from the antennae of the navel orangeworm, *Amyelois transitella* Walker (Lepidoptera: Pyralidae). These recombinant proteins have been overexpressed in LB medium using transformed BL21(DE3) cells. Proteins in the periplasmic fractions were extracted by three cycles of freeze-and-thaw, and purified by ion-exchange chromatography (DEAE, Mono-Q) and gel filtration (Sepharose). Fractions were analyzed by SDS gel electrophoresis and liquid chromatography-mass spectrometry.

Pure protein fractions (>98%) were desalted, lyophilized and stored at -80°C until use. We have also developed a novel binding assay based on the separation by a centrifugal filter device of bound and free ligands. Using this novel binding assay, we have demonstrated that the previously identified pheromone constituent, (*Z,Z*)-11,13-hexadecadienal bound to a recombinant pheromone-binding protein (AtraPBP1) with apparent high affinity. Screening of other potential ligands showed that a related acetate compound had similar affinity to AtraPBP1. On the other hand, electrophysiological recordings from sensilla trichodea (single sensillum recordings, SSR) in male moth antennae indicated that the navel orangeworm possess multiple olfactory receptors neurons (ORNs), which are stimulated by constituents in hexane extracts from pheromone glands. To determine the active constituents in these SSR-active fractions, we used gas chromatography coupled with an electroantennographic detector (GC-EAD) and having male moth antennae as the sensing element. These molecular- and sensory physiology-based approaches led to the identification of new constituents of the sex pheromone system of the navel orangeworm.

FLORAL DIVERSIFICATION, PARASITOIDS AND CABBAGE PESTS

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Diversifying agroecosystems with floral non-crop vegetation has the potential to conserve natural enemies and enhance pest control. Many adult parasitoids utilize floral nectar sources which has been shown to increase their longevity and fecundity in numerous laboratory studies. However, diversified habitats may likewise benefit the pest or fourth trophic level. We tested the pest control potential of buckwheat, *Fagopyrum esculentum* Moench, in cabbage fields over four years, 2000-2003. Pest and parasitism rates were monitored in cabbage plots (12 x 20 m) with and without 3 m wide buckwheat borders. Floral borders did not increase egg, larval or pupal densities of cabbage looper *Trichoplusia ni* (Hübner), imported cabbageworm *Pieris rapae* (L.) and diamondback moth *Plutella xylostella* (L.). Buckwheat increased parasitism rates by *Voria ruralis* (Fallen) on *T. ni* larvae and *Cotesia rubecula* (Marshall) on *P. rapae* larvae consistently over four years. Parasitism by *Diadegma insulare* (Cresson) on *P. xylostella* larvae was higher in buckwheat than control plots in the first year, and parasitism by *Euplectrus plathypenae* (Howard) on *T. ni* larvae was lower in buckwheat than control plots in the second year. This study suggests that buckwheat can potentially enhance parasitism rates but not pest densities or hyperparasitism rates.

NEW INVASIVE BARK BEETLES THREATEN URBAN FOREST LANDSCAPES

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The invasion of exotic species has led to major ecological and economic problems. Two recently detected exotic bark beetles (Scolytidae) pose a threat to urban forest landscapes in the United States, and their current distributions, life cycles, and potential impacts will be presented. First, the banded elm bark beetle, *Scolytus schevyrewi*, originating from Northern Asia was detected in Colorado and Utah in April 2003 as part of the USDA APHIS/Forest Service Rapid Detection and Response Pilot Project. To date, the beetle has been found in over 20 states, but not in Canada or Mexico. Adult *S. schevyrewi* primarily colonize weakened elm trees (*Ulmus* sp.) and may interact with the European elm bark beetle, *Scolytus multistriatus*, and Dutch elm disease, other exotic pests of native and introduced elms in the US. Another newly discovered bark beetle in the US is the Mediterranean pine engraver, *Orthotomicus (Ips) erosus*, which was first trapped in 2004 in large numbers in five counties in California (Kern, Tulare, Fresno, Madera, and Merced). *Orthotomicus erosus* is a pest of pines in the Mediterranean region, South Africa, and Chile. In California, it has been collected in association with cut logs of exotic pines that are widely planted in the Central Valley. This beetle is associated with an ophiostomoid fungal pathogen that may negatively impact exotic pines.

ALTERNATIVES TO THE USE OF METHYL BROMIDE IN POST-HARVEST INSECT CONTROL

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In the early 1990s, it was discovered that methyl bromide was an ozone-depleting chemical and would be phased out according the international Montreal Protocol. After reconciliation with the U. S. Clean Air Act, phase-out was scheduled to be complete on January 1, 2005. All uses of methyl bromide except those for quarantine and pre-shipment (QPS) would end at that time. That started the clock ticking on finding alternative treatments to replace non-QPS uses of methyl bromide. In post-harvest, alternatives can be divided into those that are derived from the use of chemicals and those that involve non-chemical use.

Chemical alternatives deal with those replacements that involve new fumigants and those that involve using chemicals to disrupt behavior patterns of insects. New and revived

treatments consist of new fumigants like carbonyl sulfide, methyl iodide, ozone, dicarbondinritrile (cyanogen) and ethyl formate. As these compounds have been investigated as potentials to replace methyl bromide, it has become apparent that none of them will serve as a drop-in for all the uses now conducted with methyl bromide. However, many of the uses of methyl bromide can be filled by one or more of these compounds and research is now needed to show the specifics of how that may be accomplished. In addition, new methods for applying older fumigants such as sulfuryl fluoride and phosphine have now been investigated for replacing some uses of methyl bromide with varying degrees of success. In addition to fumigants, chemicals that affect insect behavior are being researched to develop methods to disrupt mating or optimize the timing of treatments. Intermixed with the research to find alternatives is the issue of registration of new chemicals for use. Some compounds are already registered, some will require a rather lengthy period to obtain registration and some do not require registration.

Non-chemical alternatives have been investigated and are being used with varying degrees of success as well. Compression used along with fumigation has been accepted in shipping 'Timothy' hay to Japan and Asian-rim countries while new methods of using heat and cold treatments have produced good results. Pathogens are also being investigated to suppress the infestations of Indianmeal moth in storage facilities and overwintering populations of Navel orangeworm in pistachio orchards. Of course, irradiation is still a viable alternative and is being used in more cases where methyl bromide was used previously. Some of these methods will require registration to be used as alternatives to methyl bromide while some will not.

DEVELOPMENT OF PROTOCOLS FOR LONG-TERM HABITAT MANAGEMENT OF OVERWINTERING SITES IN CALIFORNIA

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A key component in the preservation of the mass winter aggregations of monarch butterflies' in California is through long-term habitat management of winter groves. Groves that support overwintering butterflies are dynamic changing systems and conditions that favor their winter aggregations can be easily altered by tree loss due to diseases, storm damage and urban development or by normal grove senescence. The management, of winter groves therefore, should be focus on enhancement activities aimed at maintaining or re-establishing favorable conditions for the roosting butterflies.

Enhancement of winter groves should be based on data obtained from the monitoring and the evaluation of certain biological and environmental variables. These variables should include: (1) wind pattern of gusty and storm winds; (2) the butterflies' seasonal aggregation pattern within the grove; (3) their winter occupancy; (4) morning and

afternoon sunlit foliage supporting roosting butterflies; and (5) sunlit areas for foraging for nectar or water and for mating.

POSTHARVEST INSECT CONTROL ON LETTUCE USING CONTROLLED ATMOSPHERE

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U.S. lettuce often faces fumigation treatment or rejection on oversea markets such as Japan because of the presence of live insects either quarantined or restricted. We conducted research on controlled atmosphere to develop effective postharvest treatment for insect control on lettuce. Ultra-low oxygen treatments at low temperatures were carried out in small- and large-scale tests to determine effective treatments against insects and their effects on lettuce quality. Insects were treated both in mall jars and pressure cookers without lettuce and in large drum chambers and in lettuce cartons on a pallet filled with commercial head lettuce. Apparatus and method were developed to conduct ultra-low oxygen treatment for a single pallet with boxed lettuce and treatments were conducted successfully. Target insects include lettuce aphid, *Nasonovia ribisnigri*, western flower thrips, *Frankliniella occidentalis*, and leafminer, *Liriomyza langei*. Lettuce aphid was relatively easier to control than thrips or leafminer flies. Effective control for lettuce aphid without significant impact on lettuce quality is possible. However, a safe ultra-low oxygen treatment to control thrips or leafminer flies seems to be difficult to achieve. Injuries to lettuce included both injuries by low oxygen and by carbon dioxide produced under anaerobic conditions in the ultra-low oxygen treatments. Injury to lettuce was related to head density as well as oxygen level and treatment time. There were also apparent variations among cultivars in susceptibility to injuries by ultra-low oxygen treatments.

A PROTOCOL FOR USING THE MITE BRUSHING MACHINE FOR MEASURING DENSITIES OF MITE ON WINEGRAPES

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Enumerative methods for estimating field populations of arthropod pests are accurate and precise, but time-consuming. The Mite Brushing Machine is a technology that can reduce the time required to obtain either absolute counts or estimates of arthropods on leaves from samples. Although this technology was investigated and recommended as a useful tool for research and commercial pest management by research entomologists and the USDA, little work to demonstrate the validity of this technique has been performed since the 1950's.

The areas of this investigation include the number of passes through the brushes to remove all arthropods from the leaf, distribution of arthropods on the collection plate, a comparison to direct counts of arthropods on leaves, accuracy and precision of various scanning methods using a dissecting scope, the accuracy and precision of this technique compared to traditional binomial sampling for arthropod pests on grapes, and an analysis of cost-benefits based on the time required to perform the protocol compared to direct counting and binomial sampling.

WILD CROP POLLINATORS: THE ROLE OF NATIVE VEGETATION IN THE MAINTENANCE OF NATIVE CROP POLLINATOR DIVERSITY.

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Crop pollination by wild insects is a natural process that can provide economic benefits to farmers and potentially provides economic incentives for conservation. Native habitats near crop fields potentially support numerous wild crop pollinators. Despite this, few studies have examined the importance of native habitats near crop fields to wild insect-mediated crop pollination. Those that have examined this relationship focus on bee-pollinated crops such as coffee and melons. However, many crops are primarily pollinated by non-bee insects, which are likely to have different habitat needs than social and solitary bees. In this talk, I will review several studies on the importance of wild vegetation in agricultural landscapes to the pollination of bee-pollinated crops by wild pollinators (native and feral) and evidence that increased pollinator diversity increases yields in these crops. Second, I will discuss two of my studies examining the importance of native vegetation to non-bee pollinators of kiwifruit and oil palms. Results from all studies on this topic indicate that the incorporation of wild vegetation into crop-dominated landscapes can provide economic benefits in crops pollinated primarily by bees. For crops pollinated primarily by non-bee insects, however, the importance of nearby native vegetation appears less economically important, with only crop-specific conservation benefits.

SCOLYTID BEETLES TRAPPED ON *PHYTOPHTHORA RAMORUM*-INFECTED COAST LIVE OAKS IN CALIFORNIA

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Sudden oak death (SOD) is an introduced disease of coast live oaks (*Quercus agrifolia*) in coastal California that is often fatal. The causal agent is the oomycete *Phytophthora ramorum*. Attack by saprotrophic beetles is a consistent feature of disease progression.

We sprayed insecticide on half the trees in 2 groups: inoculated in 2002 with *P. ramorum* and mock-inoculated (wounded only), and placed sticky traps on the sprayed trees to monitor beetle responses. In the absence of the insecticides, more than 50% of the infected trees were colonized by scolytid beetles within one year. Traps on inoculated trees caught significantly more beetles than those on mock-inoculated trees. We present species abundance and sex ratios of the principal saprotrophic beetles that were trapped during the two beetle flight periods in 2003.

RESPONSES OF SCOLYTID BEETLES TO COAST LIVE OAKS INFECTED WITH *PHYTOPHTHORA RAMORUM*

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Sudden oak death (SOD) is caused by *Phytophthora ramorum*, an oomycete that was introduced recently into coastal California. Although this pathogen has a broad host range, coast live oaks (*Quercus agrifolia*) and tanoaks (*Lithocarpus densiflorus)* suffer the greatest mortality. Infected coast live oaks exhibit bleeding stem cankers that are consistently colonized by ambrosia and bark beetles (Coleoptera: Scolytidae) while the foliage is functional and apparently healthy. Survival analysis shows that beetle colonization is strongly associated with decreased survival. In 2002, we mechanically inoculated healthy coast live oaks with *P. ramorum*, followed by application of insecticide in half of the trees to prevent beetle colonization. Insects landing on trees were monitored using sticky traps. We report here the differential survival of infected coast live oaks as a function of insecticide treatment. Among the beetle species trapped, five were scolytids not reported to attack the trunks of living trees. Insecticides were not completely effective in preventing beetle colonization, apparently due to bark damage caused by the pathogen. Evidence has recently emerged suggesting that some trees may show resistance to *P. ramorum*. The effects of ambrosia beetles tunneling 10 cm and deeper into the sapwood may compromise the defenses of infected trees.

REDUCING PESTICIDE RUNOFF FROM NURSERIES

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Reduction of non-storm runoff from nurseries has become a major focus of regulatory programs nationwide. The greenhouse and nursery industry has been at the forefront of this regulatory pressure in many locations, because of the industry's more intense use of agricultural chemicals, as well as the proximity of many nurseries to high population areas. We have developed a program for growers in San Diego County to assist in minimizing or eliminating the runoff potential from their nurseries and greenhouse operations. Funding for this project is provided by the State Water Resources Board Proposition13 grant program, and by several grower organizations. This program involves the use of self assessments to review the growing operation, assistance in choosing best management options to improve runoff issues, and educational workshops and tours to expose growers to implemented practices that will improve their water quality situation. We have also developed materials that will aid the growers in meeting the regulatory requirements, including a water quality record keeping system and training modules for growers to use in educating their labor force with regard to water quality issues. We have conducted over 160 site visits to growing operations in the last year, and provided more than 800 meeting attendees with information to improve their growing operations and meet regulatory requirements. In addition, we have worked closely with regulatory personnel regarding implementation of the regulations, to make them workable for both regulatory personnel and growers.

BEE COMMUNITIES IN A COMPLEX, UNPREDICTABLE DESERT LANDSCAPE. WHY IS THE FAUNA SO DIVERSE?

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Arid environments supposedly support some of the most diverse bee faunas worldwide. Yet little tangible evidence exists to support this claim, or elucidate its causes. To explore these observations, we conducted a four-year study of the bee fauna of Grand Staircase-Escalante National Monument (GSENM), southern Utah. Located on the Colorado Plateau at the interface of the Mojave and Great Basin Deserts, GSENM supports a diverse assemblage; over 450 species have been identified thus far—more than 10% of the bee fauna in the U.S. Here, we provide an overview of this fauna, including possible reasons for the diversity based on results from the first two years' data. Seasonal turnover is high across the monument; only 30 to 40 % of the bees were similar between

any two consecutive months. Bee communities here show a high rate of spatial turnover as well. One-hectare plots varied nearly a hundredfold in species richness. Ordination using non-metric multidimensional scaling shows that topographical complexity is one likely cause, as are the heterogeneous floral landscape and patchy, unpredictable water resources. Additionally, attributes of bees (size, as a measure of ability to disperse, and floral specialization) appear to influence overall distribution.

THE RELATIONSHIP BETWEEN COLORADO POTATO BEETLE (COLEOPTERA: CHRYSOMELIDAE) AND FLUROXYPYR RATE FOR VOLUNTEER POTATO SUPPRESSION

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The presence of volunteer potatoes (*Solanum tuberosum* L.) throughout potato crop rotations can lead to a failure in breaking the disease and pest cycles associated with potato. In greenhouse bioassays, Colorado potato beetle ("CPB", *Leptinotarsa decemlineata* Say) larvae were placed in densities of 0, 5, 10 and 40 plant^{-1} (cv. Russet Burbank). The presence of as few as 5 CPB produced suppression of solanaceous weeds comparable to fluroxypyr alone; as much as 94% less fluroxypyr was needed when CPB were present. Above ground "AG" biomass plant^{-1} at the sublethal rate of 14 g ae hectare^{-1} for CPB densities of 5, 10, and 40 resulted in mean weight reduction compared to CPB absence by 69%, 69%, and 88% respectively. AG biomass plant^{-1} at 0 g ae hectare^{-1} fluroxypyr for CPB densities of 5, 10, and 40 caused mean weight reduction when compared to CPB absence by 24%, 22%, and 90% respectively. We are quantifying the interaction of fluroxypyr with herbivory on volunteer potato fitness. Our overall objective is to determine how much we can reduce herbicide applications/rate for potato in the presence of substantial CPB feeding. Our results demonstrate complete skeletonization of potatoes within 14 days post spray when CPB densities of 40 per plant are maintained.

MONITORING OF CITRUS PEELMINER (*MARMARA GULOSA*) IN THE CENTRAL VALLEY OF CALIFORNIA USING INTERNET-BASED REPORTING METHODS

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Recent innovations in the use of the Internet that enable data entry and pest reporting provide an opportunity for monitoring the distribution of citrus peelminer, *Marmara*

gulosa (Lepidoptera: Gracillariidae), in citrus and surrounding cropping systems. Through the use of web-browsing software and a personal computer connected to the Internet, citrus growers and consultants are able to share information regarding presence, pest pressure, location, life stage and hosts of citrus peelminer that enable our laboratory to study the spatial distribution of this insect in greater detail than would otherwise be possible. ArcIMS (Internet Mapping Services) software provides the ability to serve maps of the Central Valley of California to the user, who in turn enters data concerning the status of citrus peelminer in citrus orchards and surrounding crops into a spatially linked Microsoft Access database. This data is processed and served back to the user via either static maps or dynamic data access. Future capabilities will include the spatial modeling of citrus peelminer distribution across various cropping patterns to determine optimal conditions for peelminer activity with the goal of reducing the impact of citrus peelminer damage in situations identified as being highly susceptible.

PHYLOGENY AND NATURAL HISTORY OF THE PAUSSINAE, AN ENIGMATIC GROUP OF BOMBARDIER BEETLES

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Paussine beetles explosively discharge defensive benzoquinones at temperatures between 55°C and 100°C. This defensive strategy effectively deters both invertebrate and vertebrate predators and it is unique to paussines and one other lineage of bombardier beetle. Paussine species exhibit varying degrees of association with ants (myrmecophily) that has led to an astounding array of morphological diversity within this group. Many species lay their eggs in host ant nests, and the host ants help raise the beetle larvae and pupae. Even though adult paussines are ant brood predators, behaviors of the host ants indicate that some paussine species are not simply tolerated guests, but may be valued by the ants. I have inferred the phylogenetic relationships within the subfamily Paussinae based on two ribosomal structural genes, a nuclear protein-coding gene, and a mitochondrial protein-coding gene providing the framework for investigating of the evolution of myrmecophily and the characters and behaviors associated with this lifestyle. In this talk, I present my work on the phylogenetics of the Paussinae and an overview of the morphology, natural history and biogeography of this little known group.

ELECTROANTENNOGRAM RESPONSES OF *CULEX QUINQUEFASCIATUS* TO BERMUDA GRASS AND RABBIT CHOW INFUSIONS

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Culex quinquefasciatus is a vector for many diseases, including bancroftian filiariasis, St. Louis encephalitis, and West Nile Virus. Female *Culex quinquefasciatus* prefer to oviposit in water rich in organic materials. For this reason, fermented infusions of Bermuda grass and rabbit chow have been used in traps for gravid females. The chemical composition and attractiveness of these infusions are dynamic, making the traps less effective over time. Identification of the semiochemicals within the infusions will allow the creation of more effective oviposition traps. Four yeast fermented infusions were prepared: Bermuda grass, Bermuda grass with lactalbumin hydrolyzate, rabbit chow, and rabbit chow with lactalbumin hydrolyzate. In an attempt to characterize previously unknown attractants, head space volatiles were collected from these fermentations by Solid Phase Microextraction (SPME). GC-EAD analysis was performed with these volatiles and gravid female *Culex quinquefasciatus*.

PHYLOGEOGRAPHIC STRUCTURE OF TONGUE LENGTH AND ITS RELATIONSHIP TO FLORAL RESOURCES IN THE LONG-TONGUED HORSEFLY POLLINATOR *PHILOLICHE ROSTRATA* (DIPTERA: TABANIDAE).

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Long-tongued horseflies (Diptera: Tabanidae) pollinate a variety of deeply throated flowers. There is substantial spatial variation in proboscis length within some species of these flies. Previous work shows that geographic structure in the proboscis length of *P. rostrata* correlates with *Disa draconis* (orchidaceae) floral morphology over space. Although coevolution has been implicated, the actual cause of variation in this group of flies remains unexplored. Two possible explanations for this are local adaptation and/or the presence of cryptic species. I examine phylogeographic structure in proboscis length for *P. rostrata* to determine 1) How does phylogenetic structure explain this variation? 2) How is the variation geographically structured with respect to phylogeny? and 3) How is this variation correlated with floral resources over space? Flies from 8 populations of *P. rostrata* were sampled over the southern part of its range in southwest Africa and analyzed using the mitochondrial gene ND4. Preliminary data suggests that proboscis length variation is correlated to geography and floral resources and not phylogeny or cryptic species.

EFFICACY OF A MIXTURE OF PHOSPHINE/CARBON DIOXIDE ON STORED PRODUCT INSECTS

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One of the disadvantages of phosphine (PH_3) as a fumigant is the long exposure times required for efficacy. This is especially true at lower temperatures. Phosphine, generated from metallic formulations, may take up 24 hours or longer to reach peak concentrations. Because of this process, the exposure time minimally recommend is generally 48 hours which eliminates quick turn around time for commodity fumigations and shipment as needed.

For this study, we determined efficacy on several stored product insect species using PH_3 directly from a gas cylinder mixture carbon dioxide 98% and PH_3 2%, (ECO2FUME Fumigant Gas by Cytec Industries Inc.). In these studies, we replaced the first 24 hours formally required for reaction time with maximum concentrations of PH_3. Starting dosages tested were 250, 500 and 1000 ppm. The egg stage was most resistant to PH_3 fumigation. However, at 26.7 ^{O}C for 24 hour exposure and a dosage of 250 ppm, an average of 84.9% mortality to eggs (1-3 days old) of the seven species tested was obtained. Under tbe same conditions with dosages of 500 ppm and 1000 ppm, average mortality was 90.5% and 98.2 % respectively. For post-embryonic stages, 98-99% mortality to pupae was obtained and 99.5% to larvae and adults was obtained. When fumigation exposure times or temperatures were increased percent mortality increased. For instance, a 36 hours exposure with a temperature of 26.7^{o}C, and dosages of 250 ppm, 500 ppm and 1000 ppm, produced an average of 91.8%, 95.6%, and 98% egg mortality respectively. When exposure was increased to the more traditional time of 48 hours mortality to eggs were, as expected, increased to 96.2% at the low dosage of 250 ppm and 100% for 500, 1000 ppm dosages respectively. Temperatures of 30^{o}C, 32.5^{o}C, and 35^{o}C for 24 hour exposure and a dosage 250 ppm produced an average of 93.8%, 96.9% and 99.7% mortality to eggs, respectively. Species tested: Indian meal moth *Plodia interpunctella*, navel orangeworm Amyelois *transtella*, red flour beetle *Tribolium castanium*, confused flour beetle *Tribolium confusum*, warehouse beetle *Trogoderma variabile*, sawtoothed grain beetle *Orzaephilus surinamensis*, and cigarette beetle *Lasioderma serricorne.*

ROLE OF INSECT GROWTH REGULATORS FOR MANAGEMENT OF *BEMISIA TABACI*

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Bemisia tabaci (Gennadius) is a cosmopolitan pest of agricultural and horticultural crops. In addition to direct feeding damage, the insect vectors over 100 plant viruses, causes debilitating plant disorders of unknown etiology and, by the excretion of honeydew, reduces the quality of harvested products. There are many challenges to the development of economically-efficient and environmentally-sound management systems for *B. tabaci.* The insect has a reported host-range of over 500 plant species, a high reproductive rate, the ability to readily disperse among hosts and breed year-round, and a propensity to develop resistance to insecticides. Significant progress has been made in understanding the biology and ecology of *B. tabaci* and the contribution of natural mortality factors in population regulation. Nonetheless, insecticides continue to play a key role in management of this pest and many new materials have been introduced over the past few decades. Efficacy remains a clear priority, however, increased emphasis is now being placed on insecticide selectivity within integrated control systems. Among these are several insect growth regulators (IGRs) which have found broad usage in both field and protected agricultural systems. Recent research on two of these, buprofezin (chitin inhibitor) and pyriproxyfen (juvenile hormone analog), will be highlighted here.

Although these IGRs had been successfully used in other parts of the world since the late 1980's they were first introduced into the US through an EPA emergency registration for control of *B. tabaci* on Arizona cotton in 1996. Research in Arizona initially focused on developing sampling plans and action thresholds for use of these materials and in integrating them into a 3-stage insecticide resistance management framework. Research also focused on examining the impact of these IGRs on non-target organisms, specifically the diverse natural enemy complex residing in cotton. Extensive, long-term sampling and field-based life table studies clearly demonstrated the efficiency, efficacy and selectivity of buprofezin and pyriproxyfen for *B. tabaci* control. The result is a truly integrated control system that relies on careful monitoring of pest populations and takes full advantage of biological and other natural sources of mortality for season-long suppression of pest populations. More recent work has focused on the integration of IGRs, neonicotinoids, transgenic *Bt* cotton and conventional insecticides within a community-wide resistance management context that strives for sustained management of this serious pest among all affected crops.

NEONICOTINOID INSECTICIDES FOR WHITEFLY CONTROL IN COLE CROPS AND LETTUCE

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Neonicotinoid insecticides are systemic in plants and efficacious against silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring. They are neurotoxins and the target site is the nicotinic acetylcholine receptor. Neonicotinoid insecticides are relatively safe for most beneficial insects, but are harmful to lady beetles when applied as foliar sprays. The neonicotinoid insecticides acetamiprid, clothianidin, dinotefuron, imidacloprid, and thiamethoxam were compared to untreated controls in randomized complete block experiments in broccoli, cabbage, cauliflower, and lettuce at the University of California Desert Research and Extension Center, Imperial Valley, California. Acetamiprid (Assail) has contact and systemic activity and has some ovicidal activity. Acetamiprid is not available to plants in the soil and must be used as a foliar spray. Clothianidin (Belay and Clutch), dinotefuron (Venom), imidacloprid (Admire and Provado), and thiamethoxam (Actara and Platinum) are systemic as foliar sprays and soil treatments. They are also efficacious when applies through drip irrigation. Imidacloprid is relatively immobile in the soil and requires precise placement for root uptake. Thiamethoxam, dinotefuron and clothiadin move readily through the soil allowing side-dress applications to be pushed into the root zone with furrow irrigation. Performance varies with the crop and method of application. Neonicotinoid insecticides are efficacious against silverleaf whitefly in cole crops and leafy vegetables when applied as soil treatments or foliar spray treatments. The neonicotinoid insecticides in our studies provide silverleaf whitefly control in lettuce and cole crops at levels acceptable to the vegetable industry.

UPDATE ON CATTS QUARANTINE TREATMENTS FOR POME AND STONEFRUITS

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Controlled Atmosphere Temperature Treatment System (CATTS) has been used to develop quarantine treatments for apples, winter and summer pears, peaches, nectarines, and sweet cherries against the internal feeding pests codling moth, *Cydia pomonella*, oriental fruit moth, *Grapholitha molesta*, Western cherry fruit fly, *Rhagoletis indifferens*, Apple maggot, *Rhagoletis pomonella*, and plum curculio, *Contrachelus nenuphar*. These treatments were developed to optimize upon the differences in plant and insect physiological responses to high temperature stress.

There are currently laboratory-scale, able to treat 120 lbs of product, half ton, and 2 ton commercial CATTS units. Efficacy tests (5,000 killed with zero survivors) have been performed on codling moth and Western cherry fruit fly in sweet cherries using two CATTS treatments in the lab scale CATTS unit. Efficacy tests against oriental fruit moth and confirmatory tests (30,000 killed with zero survivors) against codling moth in peaches and nectarines have been performed using two CATTS treatments in the lab-scale CATTS unit. Efficacy tests against codling moth and oriental fruit moth have been performed on apples using the 2 ton commercial CATTS unit. Confirmatory tests against codling moth in apples have been performed using the laboratory-scale CATTS unit. These treatments will help both conventional and organic fruit industries in providing a rapid, direct postharvest quarantine treatment with little effect on commodity quality.

HOW NATURAL ENEMIES AND APHID POPULATION DYNAMICS AFFECT ORGANIC BROCCOLI HARVEST

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The cabbage aphid (*Brevicoryne brassicae* L.) is the primary broccoli (*Brassica oleracea* L.) pest in Monterey County. Their ability to contaminate a broccoli head has sometimes led to zero-tolerance spray thresholds, thereby causing ecological harm. To improve upon these management practices, aphid arrival time, within-plant colony location and abundance of natural enemies were tested against organic broccoli harvest. Cabbage aphids predominately colonized the outer leaves of a broccoli plant. These colonies, however, did not significantly influence broccoli harvest. Only center-located aphids were correlated with head infestation for both field seasons. Aphid arrival time into a field was strongly correlated with harvest, with early arriving aphids being less likely to infest a head. This was in part due to natural enemies, particularly syrphid larvae (Syrphidae), which were in greatest abundance in response to early aphid colonizers. Natural enemies demonstrated a capability to positively affect harvest, although their success seemed dependent upon aphid arrival time. Therefore, future research efforts should focus on management practices that encourage the early establishment of natural enemies.

NATURAL ENEMY ABUNDANCE AND DISTRIBUTION IN ASSOCIATION WITH ALFALFA TRAP CROPS IN ORGANIC STRAWBERRIES

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Integrating vacuumed alfalfa trap crops into organic strawberry fields has provided an effective management tool for increased control of the western tarnished plant bug (WTPB), *Lygus hesperus* Knight, the primary cosmetic pest in organic strawberry production. However, little is known about the functionality of alfalfa trap crops on natural enemy populations. Is it possible for alfalfa to act both as a sink for herbivores and a source of predators in organic strawberry fields? Of the several Hemipteran generalist predators found in organic strawberry systems with alfalfa trap crops, big-eyed bugs (*Geocoris spp*.) were the most abundant likely predator of WTPB. *Geocoris* spp. were most plentiful in strawberry fields with machine-vacuumed trap crops only, when compared to fields with whole field vacuuming programs without alfalfa trap crops. These treatment differences were recorded at a distance of up to 16 strawberry rows away from the trap crop. Vacuuming an alfalfa trap crop itself had little effect on *Geocoris* densities. However, big-eyed bugs were susceptible to vacuuming treatments in strawberry rows, which reduced their abundance. Regardless of vacuuming treatment, big-eyed bugs were more abundant in strawberry rows when compared with associated alfalfa trap crops. In organic strawberries, vacuumed alfalfa trap crops can potentially provide WTPB suppression in two ways: mechanical control (vacuuming) and biological control (increased big-eyed bug abundance).

REDUCING PESTICIDE RUNOFF IN PRUNES WITH INTEGRATED PRUNE FRAMING PRACTICES (IPFP) PROGRAM

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Integrated Prune Farming Practices (IPFP) program revolves around monitoring and developing treatment thresholds for pests, plant nutrition, and irrigation needs. Results from the past five years' pest monitoring and applying pesticide treatments only when a pest reaches treatment threshold indicated that many pounds of pesticides and their application cost could have been saved. An estimate of the five year total of pesticides that could have been saved by all prune growers following this projects pest monitoring and treatment guidelines is 7,356,708 pounds of a.i. of pesticides. Tree water status monitoring indicated that many growers in the program are applying more water than needed for best production. Estimates of savings appear to be around 40 percent when compared to current "Conventional" irrigation scheduling practices. Growers saved an average of over 40 pounds of Nitrogen per acre in 2001 and 12 pounds of Nitrogen per acre in 2002. Over the past five years 113 educational meetings, which discussed progress and implementation of the data being developed, were held for an audience of

over 3886 individuals interested in prune production. Fourteen newsletters were published and distributed to all 1,400 prune growers in California plus about 500 related industry members about the progress of the project.

POTENTIAL EFFECTS OF CLIMATE CHANGE ON EASTERN NORTH AMERICAN MONARCH BUTTERFLY (*DANAUS PLEXIPPUS*) DISTRIBUTIONS

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Monarch butterflies appear to use very restricted climatic niches during their wintering period in central Mexico, and as they breed in the northern US. We used ecological niche modeling to identify areas adequate for monarch survival under both current and future climate scenarios. This approach permits testing and validation of model predictivity, and yields quantitative, testable predictions regarding likely future climate change effects. Our models predicted monarch presence with a high degree of accuracy, and indicated that precipitation and diurnal temperature range were key environmental factors in making winter locations suitable for monarchs. When we projected monarch distribution onto future climate scenarios (using Hadley Centre climate models), we found that conditions were likely to be inadequate across the entire current winter range, particularly owing to increased cool-weather precipitation that could cause increased mortality. We have also used data from the Monarch Larval Monitoring Project (MLMP) to model effects of climate change on the monarchs' summer habitat. Preliminary results show that suitable summer habitat is likely to move northward, but will still exist in 50 years.

S.O.S. (SYSTEMATICS AT OREGON STATE)

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With a tradition dating back to the founding of the university, systematic entomology at Oregon State University remains a vibrant and dynamic field. Recognizing the vital role systematics plays in entomological research, Oregon State fosters the advancement of modern systematics through the development of research facilities and programs. A highlight of this commitment is the research and training program developed by Drs.

Andrew Brower and Darlene Judd. Students of the Judd/Brower systematics lab are encouraged to blend the rich history of systematics with modern tools and approaches to address current and past problems in entomology. This presentation will provide an overview of systematic entomology at Oregon State, discussing past accomplishments, present endeavors and future directions.

MASS REARING OF CITRUS PEELMINER, *MARMARA GULOSA* AND IT'S EULOPHID PARASITE, *CIRROSPILUS COACHELLAE*

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Mass rearing of citrus peelmier, *Marmara gulosa* Guillén and Davis (Lepidoptera: Gracillariidae), a pest of citrus and other crops in the Southwestern United States, was successfully conducted in the laboratory. The fruit of a number of host plants were compared for suitability of rearing citrus peelminer including grapefruit, bell pepper, eggplant, cucumber, zucchini. Of the host plants tested, Italian zucchini squash was the optimum plant host for rearing citrus peelminer because of its year-round availability, its ability to stay fresh the full generation time, and because of the relatively high number of peelminer produced per fruit. A natural enemy of citrus peelminer, *Cirrispulus coachellae* (Hymenoptera: Eulophidae), was introduced from southern California to the laboratory. Mass rearing of the parasitoid showed promise when the parasites were first introduced to the peelminer-infested zucchini. The number of peelminer increased about 4-6 times from the first generation to the second generation, but in subsequent generations the colony completely collapsed. The difficulty of mass-culturing this parasitoid is discussed.

MORTALITY OF WHEAT STEM SAWFLY LARVAE, *CEPHUS CINCTUS* NORTON (HYMENOPTERA: CEPHIDAE) AT HIGH TEMPERATURES

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Experiments were conducted to determine the mortality rates of diapausing wheat stem sawfly larvae, *Cephus cinctus* Norton at high temperatures under laboratory conditions. Lethal temperatures and times for predicting mortality were calculated for the diapausing larvae at over 6 hour time intervals using probit analysis. For each experiment, 6 different temperatures were used, with 16 larvae at each temperature. The experiment was replicated three times. The results show that mortality increased with increasing temperatures, and for a fixed temperature, the LT_{50} was lower for longer time intervals.

In the greenhouse heat bulbs were used to determine the temperature measurements at different sawfly-cut stem positions. The inside and outside temperatures at three points

along the sawfly-cut stem were measured. The mortality and position of the diapausing larvae inside the cut stem was determined by dissection after exposing them to high temperature for six hours in the greenhouse. There is unexplained larval mortality in the field after atypically high temperatures, and this experiment is conducted to determine the impact of high temperature on survival in the field.

THE INFLUENCE OF SPRAY ADJUVANTS ON THE INSECTICIDAL ACTIVITY OF SPINOSAD IN VEGETABLES

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Field and laboratory studies were conducted to investigate how the addition of spray adjuvants to spinosad influenced its insecticidal activity against *Liriomyza* leafminers and lepidopterous larvae in leafy vegetable and melon crops. Studies were also designed to evaluate the knockdown and residual mortality of spinosad against lepidopterous larvae when applied with a buffer to produce an acidic spray solution. Results from 2000 and 2001 indicated that spinosad (Success®) applied without an adjuvant appeared to provide the most consistent adult mortality of *Liriomyza* leafminers in melons. In contrast, the addition of a penetrating surfactant (crop oil concentrate) resulted in significantly greater larval mortality consistent with the leafminer feeding behavior. A similar study in 2004 showed that addition of an oil-based biopesticide (Pyganic®) to an organically approved formulation of spinosad (Entrust®) resulted in a similar insecticidal response. Efficacy of Success against lepidopterous larvae and western flower thrips was not improved using a spray surfactant. However, addition of buffering agents to Success spray solutions significantly influenced efficacy against beet armyworm and cabbage looper. Lab bioassays and field studies showed that knockdown mortality was not affected, but residual efficacy was significantly reduced when Success was applied in an acidic (pH 4.2) spray environment.

INFLUENCE OF NON-CROP PLANTS ON STINK BUGS (HEMIPTERA : PENTATOMIDAE) AND THEIR NATURAL ENEMIES IN TOMATOES

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The effects of weed hosts on stink bugs (*Euschistus conspersus* and *Thyanta pallidovirens*), and a nectar source on natural enemies of stink bugs were investigated in the Sacramento Valley of California. Eight processing tomato fields, each having one border that was comprised of weed hosts of stink bugs (cheeseweed, wild radish and mustard), and an opposing border with no weeds were evaluated for stink bug densities and fruit damage. *E. conspersus,* the predominant species, densities were significantly

higher in tomatoes adjacent to weedy host borders than in tomatoes adjacent to a non-host border, during the first sampling period. Mean number of *E. conspersus* per sample during the second sampling period was also greater in the host border treatment than in the non-host border treatment, but the difference was not significant. Mean number of *T. pallidovirens* per sample was greater in the non-host border during both sampling periods, but the difference was not significant. Mean percentage fruit damage by stink bugs was greater adjacent to the host border than the non-host border, but the difference was not significant. Stink bug egg parasitism and generalist predator populations adjacent to a sweet alyssum (*Lobularia maritima*) border and an unplanted control border were compared. Sentinel egg mass parasitism was significantly greater .3 m from alyssum borders than .3 m from the control border, in the second and third sample periods, and significantly greater at 6 m from alyssum borders than in the control during the third sampling period. *Jalysus wickhami* trap catch was significantly greater in the alyssum treatment than the control, during the first period. We detected no other significant difference in predator populations in alyssum and control treatments. Results of these two studies reveal insights into the farmscape ecology of stink bugs and their natural enemies, and assist in the development of a farmscape management plan for stink bug control.

OPERATIONAL RESPONSE TO WNV: INTEGRATION OF SCIENCE, SURVEILLANCE, AND PRACTICAL FIELD EXPERIENCE

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Mosquito control in California is carried out primarily at the local government level by special districts and county health departments. San Mateo County Mosquito Abatement District (SMCMAD) is one example of how these agencies have used the principles of Integrated Pest Management to respond to the arrival of West Nile virus (WNV). The SMCMAD was established in 1916 in response to salt marsh mosquitoes. Early surveillance identified diked, reclaimed salt marshes as the primary source of mosquito larvae and suggested that they could be controlled at the source by physical and chemical means. This program has evolved with the changing ecology of the San Francisco Bay. When surveillance demonstrated that underground sources had become a significant source of mosquito development, the District began treating storm drain systems and utility vaults. These sources now make up a major portion of control program during summer months. The mosquitoes produced in these sources, *Culex pipiens*, are an efficient vector of WNV and an important threat to public health. In recent years, storm drain treatment has been further expanded and adult mosquitoes collected in traps are now tested for WNV.

The District continues to evaluate its programs, using surveillance to prioritize the location and timing of control, and evaluate its effectiveness. The materials and equipment used continue to evolve. District staff conduct field trials of new materials and

communicate regularly with other districts, the state health department and university researchers about new control methods.

EFFECT OF HEIGHT AND DISTANCE ON VOLATILE COLLECTION FROM WHEAT INFESTED WITH WHEAT STEM SAWFLY

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The wheat stem sawfly (WSS), *Cephus cinctus* (Hymenoptera: Cephidae) is a difficult pest to control given that it lives most of its life inside the wheat stem. The use of parasitoids as a potential method of control is under study. The present work is intended to provide valuable information on the effectiveness of an open volatile collection system under greenhouse conditions leading to the eventual use of this system in the field. The quantification of plant volatiles to improve the efficiency of parasitoids in controlling this pest was also analyzed. The collection of plant volatiles, by wheat plants infested with WSS, at three different plant heights and the dispersal of these volatiles under greenhouse conditions was evaluated. Wheat plants were planted every two weeks and infested by WSS when the second node of the main stem was detectable (Zadoks 35). Using a portable volatile collecting system volatiles were collected from infested and uninfested plants at three different plant heights and at two different distances for 2 hr intervals. The volatiles were analyzed with a gas chromatograph-mass spectrometer (GC-MS) system quantifying the compounds present. The results revealed that greater amounts of some biologically active compounds are collected at the base of infested plants, and amounts collected decreased with increasing collection height and distance from the plant.

OVIPOSITION PREFERENCE AND LARVAL PERFORMANCE OF WHEAT STEM SAWFLY (HYMENOPTERA: CEPHIDAE) ON WHEAT AND CHEAT GRASS (CYPERALES: POACEA)

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Wheat Stem Sawfly, *Cephus cinctus* Norton, oviposition preference and larval performance on wheat, *Triticum aestivum* L and Cheat Grass, *Bromus tectorum* L. was examined during the 2004 growing season of wheat in field conditions. After 6 sampling dates, the mean percentage of stems oviposited was higher (39.3%) in cheat grass compared with wheat (16.8%). Mean number of eggs by stem was slightly greater in cheat grass (1.97 ± 0.10) than those in wheat (1.71 ± 0.12). Larval infestation was also

significantly greater in grass (55.7%) than in wheat plants (28.4%). The mean number of larvae feeding in cheat grass stems was also greater (1.26 ± 0.02) than in wheat stems (1.07 ± 0.02). Larvae developed well in both the wheat and the grass. However, larvae feeding on wheat were 3.9× heavier than larvae feeding on grass. Survival rates from first instar to winter diapause larvae were higher in wheat (84.2%) compared with those in grass (43.6%).

SPATIAL PATTERNS OF PD AND GWSS AT MULTIPLE SCALES: APPLICATION TO EPIDEMIOLOGY AND MANAGMENT

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The progression of Pierce's disease (PD) in vineyards and across a landscape is dependent upon factors related specifically to four components; the vector (in this case the glassy-winged sharpshooter (GWSS)), the pathogen (*Xylella fastidiosa* causing PD), the host (grapes), and the environment. When conditions in all four of these areas are optimal, disease spreads with devastating consequence as in Temecula California in the late 1990s. Conversely, sub-optimization within any of the four categories can slow or stop disease progress. The science of epidemiology seeks to determine how the 4 components listed above interact, with the goal of creating long-term, sub-optimal conditions for disease spread. Achieving this goal will enable California producers to continue growing grapes in areas known to have PD and GWSS.

In an attempt to identify sub-optimal conditions for PD spread, we have documented the distribution of GWSS on an areawide basis. These data have been managed and analyzed in a GIS to prioritize sites for vector-reduction strategies. We also have identified the spatial distribution of PD at two scales; within infected grape shoots and within infected vineyards. At the plant scale, our data indicate that the most basil leaf petioles have the highest probability of being positive for PD, when tested by ELISA. Since identification of PD-infected vines is difficult, this study informs the field scientist from where tissue should be collected to have the best chance of detecting *Xylella.* At the field level, we have shown that the distribution of infected vines in a vineyard depends on the overall proportion of infected vines in the vineyard. In vineyards with <0.1% PD, there was no spatial structure to the distribution; under these circumstances the best way to monitor for disease is to census the vineyard. Vineyards between 0.1% and 1% PD infection showed a trend from areas of high infection to low infection. The high infection areas were always located near citrus. Vineyards with infection between 1% and 5% had random patterns of disease and those >5% had clumped patterns of infection. With the information gained in this study, we are developing a sequential sampling program that can be used by growers to determine where PD is in their vineyards. Finally, we are in

the process of modeling the spread of PD within a vineyard and an area. We are using a delayed differential equation model that is allowing us to simulate disease spread. Through this process we hope to identify components that are the most critical for spread. These components then can be targeted in management strategies against GWSS-vectored PD.

COLONIZATION OF LYGUS NYMPHAL PARASITOIDS IN CALIFORNIA

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Lygus hesperus is native to the western United States and is a pest of numerous field and seed crops. In California, it is a key pest of cotton and strawberries, both highly valued crops. Extensive surveys for natural enemies in the western United States have found one egg and two nymphal parasitoids attacking *Lygus* species, primarily *L. hesperus*. However in central California surveys in alfalfa by ourselves and others have failed to find any nymphal parasitoids. Recent, limited collections along the central coast of California, a strawberry growing region, suggest *Lygus* spp. are either attacked at very low levels by nymphal parasitoids, or not at all. Beginning in the early 1970's the USDA ARS initiated importation of parasitoids associated with *Lygus rugulipennis* infesting alfalfa in central Europe. Van Steenwyk and Stern attempted but failed to establish *Peristenus stygicus* during the mid 70's in the southern region of the San Joaquin Valley in central California. Importation of nymphal parasitoids into the eastern United States during the 1980's, however, successfully reduced *Lygus lineolaris* infesting alfalfa, a close relative of *L. hesperus*.

Interest among Canadians in the importation of these same parasitoids in the late 1990's stimulated our interest in re-examining importation of *Peristenus* spp. into California. Several populations of *Peristenus stygicus* and *Peristenus digoneutis* were cleared through quarantine (USDA ARS, Delaware) and reared in Sacramento and released initially at a nearby study site of alfalfa. Populations of parasitoids were collected from southern France, central Italy and Spain by CABI Bioscience and the European Biological Control Laboratory, USDA ARS. Beginning in 1999, parasitoids have been released at several sites in central California, both inland and on the coast.

Parasitism has increased each year at our original release site of alfalfa in Sacramento. Three years following our last releases there, we continue to find abundant numbers of both *P. stygicus* and *P. digoneutis*. Maximum summer parasitism has increased each year since releases were made, reaching 90% summer 2004. Parasitized nymphs of *L. hesperus* and *Closterotomus norvegicus* have been collected from nearby vacant lots

infested with black mustard and wild radish. Identification of adults is pending. These results indicate that these parasitoids are permanently established in the Sacramento region. Over the same period of time, maximum *Lygus* counts have varied from 3 to 14 per sweep, and appears to be declining.

In contrast to results at the first release site in Sacramento, parasitism at our other central California release sites, including one at UC Davis has yet to increase, despite additional releases in 2002 and 2003. However at one of our new central coast sites we recovered parasitoids, as larvae, at a control site 300 m from where they were first released 6 weeks earlier. Only the introduced parasitoids *Peristenus stygicus* and *P. digoneutis* were recovered, i.e. no native braconids (identification by H. Goulet, Agriculture and Agri-Food Canada). Native parasitoids, *Peristenus* nr. *howardi*, have been recovered from *C. norvegicus* at the same locations (identifications by H. Goulet).

PHYLOGENY AND HISTORICAL BIOGEOGRAPHY OF THE WORLDWIDE DRAGONFLY GENUS *SYMPETRUM* (ODONATA: LIBELLULIDAE)

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The taxonomy of the genus *Sympetrum* is currently in turmoil with a variety of species-level disputes, as well as disagreements over which taxa actually belong in the genus. The genus lacks any unique characters to define the taxon; however, the genus is defined by a "unique combination" of characters. These characters are shared with several other libellulid genera, but no other genus shares *all* these characters that define *Sympetrum*. Species of *Sympetrum* occur on all continents except Australia, and the genus has over 60 species worldwide. While many species have a Eurasian distribution, at least 15 species are found in North America. The geographic origin of the genus is likely Eurasian, which suggests that the ancestors of the North American species came from Europe, Asia, or a combination of the two. In this study, we use DNA sequences from three genes (EF1α, 16S, & 12S) to test the monophyly of the genus. With this robust phylogeny, we then discuss the historical biogeography of the genus with emphasis on the origin(s) of the North American taxa.

NEONICOTINOIDS - CROSS-RESISTANCE POTENTIAL AND IMPORTANCE IN CONTROLLING COTTON PESTS

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Neonicotinoids are an important class of insecticides used extensively worldwide against *Bemisia tabaci* (Gennadius) and many other insect pests. When resistance occurs to a

particular insecticide, it is often assumed to extend to all members of the class. Laboratory bioassays were carried out on three imidacloprid-resistant strains to compare resistance and cross-resistance patterns by systemic uptake bioassays with acetamiprid, dinotefuran, imidacloprid and thiamethoxam. An imidacloprid-resistant strain with 94-fold resistance originally collected from Imperial Valley, CA, did not show cross-resistance to acetamiprid, dinotefuran or thiamethoxam. A Guatemala-resistant strain that was also highly resistant to imidacloprid (RR=87-fold) showed low levels of cross-resistance to acetamiprid and thiamethoxam. However, dinotefuran was more toxic than either imidacloprid or thiamethoxam to both resistant strains as indicated by low LC_{50}s. By contrast, a Q-biotype Spanish-resistant strain of *B. tabaci* from southern Spain, highly resistant to imidacloprid (LC_{50} 25 K μg/ml) demonstrated high cross-resistance to the three related neonicotinoids. To further assess the expression of cross-resistance to neonicotinoid insecticides, three field populations of *B. tabaci* from three different locations in the southwestern USA were also monitored periodically to determine their susceptibilities to acetamiprid, dinotefuran, imidacloprid, and thiamethoxam Field strains expressing different levels of resistance to imidacloprid did not always show cross-resistance to related compounds as in the case of a population from Arizona having an LC_{50} of 115 μg/ml to imidacloprid, but exhibited only 8 and 9 μg/ml to dinotefuran and thiamethoxam, respectively. In general, among the neonicotinoids, dinotefuran was the most toxic of the four neonicotinoids against field populations of whiteflies. Although structural differences among compounds may affect vulnerability to degradation by metabolic enzymes, or differences in target site receptors may influence susceptibility to specific insecticides, comparison of whitefly responses from various geographic regions to the four neonicotinoids indicates the importance of ecological and operational factors on development of cross-resistance to the neonicotinoids.

BEHAVIORALLY-MEDIATED EMERGENT IMPACTS IN MULTIPLE PREDATORS AND PREY FOOD WEBS

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Previously, we found that a diverse guild of small (<1 cm) carabid and staphylinid beetles are the most important fly egg predators, whereas a single larger species, *Pterostichus melanarius*, is primarily an intraguild predator of small beetles. Further small beetles prefer to feed on aphids, and will reduce their predation on fly eggs when aphids are abundant. Recently, two interesting examples of behavior-mediated changes in egg predation have altered our view of trophic structure in this system. First, we performed an experiment where we added aphid alternative prey, the intraguild predator, or both to cages containing small beetles and fly eggs. We observed reduced levels of egg predation when either aphids or *P. melanarius* were on their own. However, in the treatment containing both aphids and the intraguild predator, egg predation returned to levels seen where neither disruptive force was present. Subsequent experiments demonstrated increased activity and incidental predation of fly eggs by *P. melanarius* in the presence of

aphids. In the second example, we added ladybird beetles to cages containing aphids and small beetles, and found that the disruptive effect of aphid alternative prey increased in the presence of ladybird beetles. This is likely because aphid dropping rates are increased in the presence of ladybirds, increasing encounter rates between small beetles and their preferred prey. These examples confirm that indirect interactions in food webs can be mediated by changes in the behavior of one or more species.

EFFECT OF GRAPEVINE CANOPY STRUCTURE ON SPIDER MITE (ACARI: TETRANYCHIDAE) BIOCONTROL

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Canopy management is an integral component of wine grape production. Several factors related to canopy architecture, including microclimate and pesticide penetration, can affect pest control. However, the impact of canopy structure on pest control is poorly understood. We have been investigating spider mite biocontrol by specialist- and generalist-feeding phytoseiid mites in Washington wine grapes. In 2003, we conducted replicated field experiments investigating effects of chlorpyrifos and sulfur on mite densities. Vine stature and associated microclimatic differences appeared to influence mite dynamics and response to chemical treatments. Thus, we are currently investigating impacts of canopy structure on the efficacy of spider mite biocontrol by chlorpyrifos and generalist phytoseiid mites.

BIOLOGICAL CONTROL OF SPIDER MITES IN WASHINGTON STATE VINEYARDS

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Spider mites (Acari: Tetranychidae) are phytophagous pests of several crops, including wine grapes (*Vitis vinifera* L.). We investigated spider mite control by phytoseiid mites, how pesticides affected the mite community, and effects of generalist phytoseiid mites and grapevine canopy structure on mite densities. We surveyed the mite community within: 1) unmanaged grapevines without chemical input, 2) managed vineyards exposed to fungicides and herbicides, and 3) managed vineyards exposed to fungicides, herbicides, insecticides and acaricides. Although unmanaged grapevines had lower spider

mite, higher generalist phytoseiid mite, and comparable specialist phytoseiid mite densities, mite densities did not differ between managed vineyards. We suspected this was partially due to widespread usage of sulfur. Field experiments supported this theory, with sulfur, alone and in combination with the insecticide chlorpyrifos, suppressing pest and predatory mites. In other open-field experiments we manipulated densities of generalist phytoseiid mites and canopy size. Increasing densities of generalists resulted in lowered spider mite densities and temporary suppression of specialist phytoseiid mites. These experiments demonstrate that generalists can significantly slow spider mite population growth in grapes, but suggest that spider mite control may be most effective through the combined impacts of generalist and specialist phytoseiid mite.

REDUCING PESTICIDES IN IRRIGATED ALFALFA THROUGH WATER MANAGEMENT AND IPM BEST MANAGEMENT PRACTICES

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The cash value of alfalfa ranges from $800 million to $1 billion/year, and is the major feed for the California dairy industry, which is worth more than $4.5 billion/year, the state's largest agricultural enterprise. Alfalfa is also the state's largest single user of water, consuming approximately 20% of the agricultural water of California. More than 80% of the acreage is surface irrigated, and runoff ranges from 0% to 25-30% depending upon location. The pesticides used in alfalfa have been detected in surface waters, the most prominent being the organophosphate group of insecticides. Winter-applied herbicides have been detected in some locations in well water, due to site-specific hydrology and system design. Alfalfa growers and UC personnel have proposed a series of measures to broadly address these water quality concerns. These include more vigorous IPM methods, strategies for reducing or substituting pesticides on sensitive areas, and a series of steps for better irrigation management. An analysis of the complexities of these issues reveals that there are no 'one-size-fits-all' solutions to the water quality issues facing alfalfa. Growers have proposed a 'water quality stewardship program' to address these issues.

CHASING WESTERN MONARCHS: NEW VIEWS ON MIGRATION ROUTES

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The notion of a bipartite monarch migration divided by the Rocky Mountains has long been a cherished part of the North American natural history canon. In fact, the data for such a complete division are almost non existent, and

depend mostly upon misleading transfer/release/recapture exercises. An effort to physically follow one part of the 1996 autumn movement in the West, and to tag emigrants, suggested a revised model for the western migration. Potential numbers and destinations of western monarchs entering Mexico instead of California will be discussed, along with conservation implications of the new information. Transfer and release of monarchs in the West subverts an accurate understanding of the species' biogeography.

ANTAGONISM BETWEEN BIOLOGICAL AND CULTURAL CONTROL TACTICS

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The Colorado potato beetle is a serious pest of potatoes worldwide. Insecticides are the primary control method against potato beetles, but these insects are developing an increasing level of resistance to many chemicals. In Washington, organic potato acreage is increasing with few cost-effective potato beetle control options. Entomopathogenic nematodes (EPN) have shown potential as biological control agents against Colorado potato beetle, and could form one component of an integrated pest management plan for the beetle's control. Locally, potato growers have begun adopting the use of mustard green manures, planted in the fall preceding potato crops, to control plant parasitic nematodes and weeds, and to reduce erosion. However, it is not known whether these mustard green manures are also toxic to beneficial EPNs. In central Washington, we surveyed potato fields for endemic EPN populations, and found that potato fields incorporating mustard green manures showed reduced infection rates by EPNs, and perhaps also reduced EPN species diversity. We next conducted laboratory bioassays, using the wax moth, *Galleria mellonella*, as a sentinel prey, to directly measure toxicity of mustard extracts to EPNs. Five *G. mellonella* larvae were placed in Petri dishes with filter paper, 1ml of treatment solution (either a water control, or mustard extract diluted in water), and 50 infective EPN juveniles per larva. The response variables were the percent of larvae dead and infected. These laboratory assays support our field survey work, with decreasing EPN infection in the presence of mustard extract.

VIRULENCE OF *METARHIZIUM ANISOPLIAE* CONIDIA PRODUCED UNDER NUTRITIONAL, PHYSICAL AND OXIDATIVE STRESS CONDITIONS

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Prokaryote and eukaryote cells constantly adapt their physiology in response to the environment. Environmental stresses activate the expression of genes encoding products that either protect the cells from the stress or participate in the repair of cellular damage. We observed that the insect pathogenic fungus *Metarhizium anisopliae* (isolate ARSEF 2575) exposed to heat-shock (45°C for 40 min), osmotic stress or nutritive stress produced conidia with double tolerance against UV-B radiation and heat, as compared to conidia produced under optimal growth conditions. In contrast, conidia produced under oxidative stress (e.g. UV-A radiation or H_2O_2) did not display enhanced conidial tolerance. Also, the effect of conidial growth conditions on virulence was tested. Conidia were produced on (a) potato dextrose agar (Difco®) supplemented with 1g L^{-1} yeast extract (Difco®) (PDAY), (b) PDAY amended with NaCl or KCl (0.6 or 0.8 M as an osmotic stress) or (c) 5 mM H_2O_2 as an oxidative stress. Additional PDAY-cultures were treated on the 3rd day of mycelial growth with heat shock (45°C for 40 min) or UV-A radiation (196 mW m^{-2} for 1 h). For nutritive stress, conidia were produced on minimal medium (MM) without carbon sources or with 3% of lactose as a carbon source (MML). Conidia from these cultures were harvested and suspended (1×10^8 conidia ml^{-1}) in sterile Tween 80 (0.1%). Insect larvae, *Tenebrio molitor* (3rd instar), were dipped for 30 seconds into each conidial suspension or sterile Tween 80 (0.1%) (controls). The insects (50 per each treatment) were maintained in 60 × 15 mm Petri dishes (10 insects per dish) under 100% RH and controlled temperature 28 ± 0.5°C. Six complete trials (repetitions) were done using a different culture batch for each trial. Conidia produced on MML (nutritive stress) proved the most virulent to *T. molitor* [approximately 2 fold more virulent than conidia produced under non-stressed nutritive conditions (PDAY)]. In addition, conidia produced on MML were approximately twice as tolerant to UV-B radiation than conidia produced on PDAY. Conidia produced on MM (nutritive stress), PDAY + NaCl 0.8 M (osmotic stress) and after UV-A irradiation (oxidative stress) had similar virulence, which exceeded that of the PDAY-conidia. Conidia from the other treatments did not have altered virulence compared with the PDAY-conidia. Accordingly, environmental stresses may improve conidial tolerance to other stresses and they also can increase virulence.

COMPARATIVE EFFICACY OF NEONICOTINOID INSECTICIDES FOR CONTROLLING CITRICOLA SCALE (*COCCUS PSEUDOMAGNOLIARUM*)

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Citricola scale has increasingly become a problem for San Joaquin Valley, California citrus growers. This insect reproduces without mating and is so prolific that the treatment threshold is approximately 1 adult female per twig in spring or an average of 0.5 crawlers per leaf in summer or fall. Populations exceeding this level can reduce yield of citrus. Once controlled for multiple years by a single spray of an organophosphate insecticide, citricola scale populations are now increasing as these types of sprays are reduced. Trials were conducted between 2000 and 2003 using several formulations and concentrations of neonicotinoid insecticides (acetamiprid, imidacloprid, thiomethoxam), applied either through irrigation or as foliar sprays on 'Washington' navel orange trees to control citricola scale. All of the neonicotinoid insecticides reduced populations of citricola scale, but varied in their degree of reduction and were inconsistent in their ability to reduce populations below the economic threshold. In general, foliar sprays of imidacloprid were superior to applications through the irrigation system. Efficacy of some of the insecticides was improved by applying them later in the year (fall) or by the addition of a low percentage of ultra fine spray oil.

WEST NILE AND ST. LOUIS ENCEPHALITIS: A TALE OF TWO VIRUSES IN CALIFORNIA

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The on-going epidemic of West Nile virus in the United States has been characterized by marked avian virulence as well as equine and human disease. The importance of WNV and SLEV virulence to avian hosts and the resulting acute viremia levels to mosquito vector competence are related to field infection patterns. Our data indicate that the elevated WNV viremia in adult Corvids is critical to driving virus into moderately susceptible urban *Culex* populations. In contrast, low SLEV viremia levels make adult birds poor hosts and nestling infection critical to virus amplification. Data are related to the current incidence of WNV disease in California.

DEVELOPMENT OF A MACROINVERTEBRATE INDEX AND USE OF PROBABALISTIC SAMPLING FOR STREAM CONDITION ASSSESSMENTS.

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We developed a macroinvertebrate index of biological integrity (IBI) for the arid and populous southern California coastal region. Potential reference sites were screened from a pool of 238 sites with quantitative GIS landscape analysis and with local condition assessments. We evaluated correlations among a suite of potential stressor gradients to identify a set of 10 independent reach, local and watershed scale stressors. To select component metrics for the IBI, we screened 61 candidate metrics for suitability with regard to three criteria: sufficient range for scoring, responsiveness to the 10 stressor gradients and minimal redundancy with other responsive metrics. Seven final metrics (Percent Collector-Gatherer + Filterers, Percent Non-insect Taxa, Percent Tolerant Taxa, Coleoptera Richness, Predator Richness, Percent Intolerant Individuals and EPT Richness) were scored and assembled into a composite IBI which was then divided into five equal condition categories. Three metrics had lower scores in chaparral reference sites than in mountain reference sites and were scored on separate scales in the IBI. A separate repeatability study and application of the IBI to an independent validation dataset confirmed that the IBI scoring is highly consistent. Data from probabilistically selected sites allowed us to develop a defensible stream condition assessment for streams the region.

PHENOTYPIC SEGREGATION OF GRAPEVINE GALLING RESPONSE TO GRAPE PHYLLOXERA (*DAKTULOSPHAIRA VITIFOLIAE* (FITCH))

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Grape phylloxera is an important insect pest of grape and continues impact the world's vineyards. Rootstocks, bred from resistant North American grape species, have been used to control phylloxera for over 100 years. However some, such as AXR#1, have failed, costing the wine industry over one billion dollars. To prevent another widespread failure, genetic mechanisms underlying the grapevine galling response to phylloxera must be understood. Tuberosities are galls that form on susceptible, woody roots, whereas nodosities are galls on young root tips. These studies are the first to examine tuberosity and nodosity formation separately. F_2 progeny from a remake of AXR were screened with phylloxera originally collected on AXR#1 roots from California. Plants were classified as resistant or susceptible based on numbers and types of galls, and Chi-square

analyses were performed to determine phenotypic segregations. Segregation of nodosity formation fits a 1:3 phenotypic distribution, thus, at least 2 genes are involved. Segregation of tuberosity formation fits a 1:1 distribution; one or two genes may be involved. It appears that separate mechanisms control nodosity and tuberosity formation; this may be confirmed by QTL analysis. DNA marker analysis on this grape population is in progress to correlate AFLP and SSR markers with resistance and susceptibility and create a linkage map. The markers will be useful in resistance breeding and serve as the basis for more detailed studies of resistance mechanisms in *Vitis*.

NOVALURON, BENZOYLPHENYL UREA CHEMISTRY FOR INSECT CONTROL

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Novaluron is a new insecticide being developed and marketed by Crompton Corporation. It is in the chemical class known as benzoylphenyl ureas that act through disruption of chitin production and deposition in the exoskeleton, and thus interrupting the normal molting process. As a result, Novaluron is very effective against the immature stages of insects (eggs, larvae, nymphs) and will not directly kill adults. Activity has been shown in the orders of Lepidoptera, Coleoptera, Hemiptera and Diptera. Novaluron was granted accelerated registration as an Organophosphate Replacement product and was registered in 2004 for use on cotton, pome fruit, potatoes and sweet potatoes. Additional crop registrations are being pursued.

WEST NILE VIRUS AND BIRDS IN CALIFORNIA

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The important relationship of birds to control of human infection with West Nile virus will be discussed. The abundance of birds in California cities combined with their epizootilogical status as reservoirs make them a key consideration in programs to limit transmission to humans.

USE OF ENTOMOPATHOGENIC NEMATODES TO CONTROL NAVEL ORANGEWORM (*AMYELOIS TRANSITELLA*) IN FALLEN PISTACHIOS

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The navel orangeworm (NOW), *Amyelois transitella* (Walker), is a key pest of pistachios in California. Overwintering larvae are unaffected by insecticides and are controlled by field sanitation. Entomopathogenic nematodes (EPNs) are effective in controlling a wide variety of insects in soil and cryptic habitats including those found in orchards. We evaluated the ability of two commercially produced steinernematid species, *Steinernema carpocapsae* and *Steinernema feltiae*, to infect NOW larvae in pistachios on the berm, in order to determine if EPNs can play a role in orchard sanitation. *S. carpocapsae* was more effective than *S. feltiae* and produced > 72% mortality at a concentration of 400 million infective juveniles/acre when nighttime temperatures were above freezing. *S. carpocapsae* was equally effective in bare and leaf-covered plots and persisted longer in sandier soil (8 weeks) than *S. feltiae*. In subsequent experiments, we evaluated the application rate and soil temperature necessary for success.

Research conducted in 2003 and 2004 demonstrated the deleterious effect of freezing temperatures, and the data from 2004 clearly demonstrate that high soil temperatures are also deleterious. Soil moisture also determined treatment success. Future research will concentrate on further quantifying the impact of temperature on treatment as well as determining the best time to apply EPNs after harvest.

BIOLOGICAL STUDIES OF PARASITOIDS (BRACONIDAE) IMPORTED FOR CONTROL OF THE OLIVE FRUIT FLY IN CALIFORNIA

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The olive fuit fly, *Bactrocera oleae* (Tephritidae), was first reported in southern California in 1998 and quickly spread throughout the state, posing a significant threat to the olive industry. To improve biological control—no effective natural enemies are currently present—an importation program was started in 2002. Three braconid parasitoids (*Bracon celer, Utetes africanus*, and *Psyttalia lounsburyi*) were collected from *B. oleae* populations in Africa, the fly's likely native range, and three (*Diachasmimorpha longicaudata*, *D. kraussii*, and *Psytallia concolor*) were imported from Mediterranean fruit fly colonies in Hawaii. Studies on their biology and behavior as

potential control agents for the olive fly were conducted at the quarantine facility at the University of California, Berkeley. We report here on methods devised to rear these species on olive fly and our findings on their fecundity, their longevity and development in response to temperature, and their host-stage preference for oviposition.

A REMOTE-SENSING OVERVIEW OF FOREST COVER CHANGE IN THE MONARCH BUTTERFLY OVERWINTERING REGION IN MEXICO

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Change in the forest cover over the primary Monarch butterfly overwintering colonies in central Mexico (Michoacan and Mexico states) has become an increasingly serious and contentious issue. Logging, some of it sanctioned, but much of it illegal, occurs within the watersheds and drainages that the Monarchs have historically occupied during their overwintering period. However, there is some debate whether such logging adversely affects the Monarch habitat and colony health. As a first step in addressing these questions, we examined the available time-series of remotely sensed imagery of the area in order to quantify the landcover change dynamics over the past 40 years. Imagery from the mid-1960's (Corona; declassified US Defense Department imagery), 1970s (Landsat MSS and aerial photography), 1980s (Landsat TM and aerial photography), 1990s (Landsat ETM and aerial photography), and 2000s (Landsat ETM and Ikonos imagery) were acquired, orthorectified, and used to categorize landcover change over this period. An automated classification algorithm was used for this work; future work will attempt to validate the results with a manual interpretation-based approach. Preliminary results show substantial deforestation over this period in areas adjacent to and within the historical colony locations.

EXPLORING THE RELATIONSHIP BETWEEN PREDATOR BIODIVERSITY AND EFFECTIVE BIOLOGICAL CONTROL

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Herbivore outbreaks are more common in agricultural than in natural communities, suggesting that restoring some elements of biodiversity to agroecosystems could improve

biocontrol. However, recent work in the predator ecology literature suggests that rising rates of intraguild predation might actually weaken pest suppression as predator biodiversity increases. In two large-scale field experiments we manipulated the species diversity of predators attacking the green peach aphid, *Myzus persicae*, on potato, *Solanum tuberosum*, to measure whether predator biodiversity influences the strength of aphid suppression. Total predator abundance at the end of the experiments (10 and 20 days for experiments 1 and 2, respectively) did not differ between Low versus High diversity treatments, indicating that rates of intraguild predation did not change with altered predator diversity. In both experiments, aphid densities were indistinguishable in Low versus High predator diversity treatments. However, species identity had a strong effect on aphid suppression, with some predator species in monoculture providing stronger and weaker aphid control than was recorded in the High diversity treatment. Our results suggest that, for this system, conservation of particularly effective natural enemies might be a more successful approach than striving to increase predator diversity *per se*.

ISOTOPIC ENRICHMENT IN HERBIVOROUS INSECTS: A COMPARATIVE FIELD BASED STUDY OF VARIATION

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Consumers are generally enriched in the stable isotopes ^{15}N and ^{13}C relative to their diets. This characteristic has enabled researchers to infer consumer trophic position and diet composition through stable isotope analysis. However, enrichment values reported in the literature vary greatly, and trophic position estimates have been shown to be especially sensitive to variation in isotopic enrichment by herbivores. In this study, we generated an experimental data set of 22 $\delta^{15}N$ and $\delta^{3}C$ enrichment means for terrestrial herbivorous arthropods. We observed overall mean enrichment values of $1.88 \pm 0.37‰$ for $\delta^{15}N$ and $-0.55 \pm 0.26‰$ for $\delta^{13}C$. The range of observed $\delta^{15}N$ enrichment values (-0.20‰ to 6.59‰) was equivalent to the total enrichment expected for 4 trophic transfers, assuming an average enrichment of 1.88‰ per transfer. The experimental data set provided no support for any of the recently hypothesized correlates of enrichment values, including the proposed roles for diet C:N ratio and feeding mode. These findings indicate that the magnitude of variation in enrichment values previously reported in the literature cannot be explained simply as an artifact of differing study methodologies, but rather represents underlying biological differences between species. The primary implications are that 1) mean enrichment will have to be calculated for each trophic link of interest, rather than relying on estimates from a broad survey of animal taxa and 2) the 'special advantage' of using stable isotope analysis to probe animal communities that are recalcitrant to other modes of study will be somewhat diminished as a consequence.

PESTICIDE REGULATION AND SURFACE WATER QUALITY IN CALIFORNIA

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The California Department of Pesticide Regulation (DPR) maintains a statewide surface water database of monitoring results (SURF). SURF currently contains > 130,000 sampling results from 48 monitoring studies, with more than 11,000 detections of 111 distinct pesticide residues. While detections have been numerous, regulatory action has been taken for a relatively small number of these materials. This presentation provides a brief overview of DPR's risk management options for detected pesticides and factors that are considered using two recent examples: diazinon and chlorpyrifos. DPR recently initiated re-evaluation of the two organophosphate insecticides. A summary of the supporting data, purpose and status of those re-evaluations is discussed. Finally, recent monitoring has identified synthetic pyrethroids in both surface water and bed sediments. In response, DPR is conducting additional monitoring and is funding research to better understand the pyrethroid occurrence and bioavailability in the water column and sediments.

INTERFACIAL FORCES AND PERMEATION OF THE CODLING MOTH, *CYDIA POMONELLA* (L.) COCOON SILK

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Differential wettability displayed by the cocoon silk of *Cydia pomonella* (L.) is related to the polarity of the wetting substance and determined by adhesion and cohesion forces as van der Waals and electrostatic forces. The objective of the study was to gain further insight on the properties of codling moth silk and its interaction with different substances. For this purpose the interaction energy between the silk cocoon surface and different water emulsions of DPA, spray-oils (winter and summer) and vegetable oils (soy, jojoba, peanut and castor-oil) was determined. The minimum equilibrium distance was measured by the capillary rise method and wetting angle was calculated using the Washburn equation. Dielectric constant, viscosity and surface tension of these substances were also measured. Silk permeation is linearly correlated with wetting angle of the substances tested. Good silk permeation was observed on oils showing contact angles between 1.96º and 3.86º. Mineral summer oils penetrate more efficiently (1.96º - 2.34º) than vegetable oils (2.51º - 3.86º). No correlation was observed between silk permeation and viscosity,

surface tension or permitivity of the different substances tested. Results are discussed with respect to the key factors affecting permeation that govern the penetration of insecticides and probably biological control agents into the cocoon. Studying the properties of codling moth silk may contribute to the development of control tactics for hibernating codling moth larvae in fruit harvest bins.

THE MYTH OF THE L50: WHY WE MUST ADOPT MORE RELEVANT MEASURES OF PESTICIDE EFFECTS ON BENEFICIAL SPECIES

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Acute lethal concentration estimates (LC50) are the most widely developed measure of toxicity and these data are often used in ecological risk assessment to protect endangered species and for assessing compatibility of pesticides and biological control agents for Integrated Pest Management (IPM) programs. The value of the LC50 as a toxicological endpoint for these uses has rarely been questioned. However, in this talk, I will show that the LC50 is not a good predictor of effect of pesticides on biocontrol agents and other non-target organisms. I will also present new approaches for the evaluation of pesticide effects that are more accurate predictors of effect and should enable us to better estimate whether pesticides are a good fit for IPM.

USING CLIMATE PATTERNS TO STUDY THE LOCAL RECRUITMENT HYPOTHESIS

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Monarchs in western North America winter at over 300 sites along the Pacific Ocean coastline, from northern California down to Ensenada, Baja California. While abundance at the majority of these sites rarely exceeds 1,000 butterflies, system-wide abundance has steadily declined for the past several years. Increasing drought conditions in the west appear to be the most likely cause for declining populations. Since the last El Nino conditions in 1998, extensive areas of western North America have undergone extreme drought which by some standards is the worst drought in the last 40 years. Dramatic declines in monarch abundance are congruent with these increasingly dry conditions. It is well known that primary production in most terrestrial systems is strongly influenced by annual precipitation levels. It follows then that these drought conditions have resulted in declining milkweed biomass at western monarch breeding grounds, which leads to lower

monarch recruitment to the migratory population. Using the Palmer Drought Severity Index, we tested for a causal relationship between drought and abundance and found significant associations in several western states, including Nevada, California, and Oregon. Drought severity was not uniform within states which also allowed tests of association at a finer geographical level. Climate data and variation in wintering abundance at this finer scale can be used to test specific hypotheses pertaining to natal origins, such as the local recruitment hypothesis. This is the notion that wintering populations derive primarily from nearby breeding ranges. The results of such hypothesis testing would strongly impact conservation strategies. While confirmation of this hypothesis would suggest a regionally focused conservation approach, rejection of the hypothesis might sway conservation efforts towards more widespread measures. These are the types of information upon which wintering habitat management and conservation guidelines should be based, and which are currently lacking for western monarch populations.

NATURAL ENEMY BIODIVERSITY AND APHID BIOLOGICAL CONTROL

Cory S. Straub and William E. Snyder

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Agricultural pest suppression has been identified as an important ecosystem service that is threatened by the loss of natural enemy biodiversity. This has generated interest in how changes in predator diversity affect pest suppression. Studies of plant, herbivore and filter-feeder communities show that resource consumption increases with greater species diversity, due to the positive effects of niche-partitioning and facilitation. However, predator-prey studies have emphasized the importance of negative interactions among predator species, suggesting that increasing the diversity of predator communities may not increase, and may even decrease, pest consumption. We used an experimental approach that controls for the confounding effects of predator density and composition to isolate the effect of increasing predator diversity on the biological control of the green peach aphid, *Myzus persicae*. In two large-scale field experiments, increasing the diversity of predator communities had no measurable effect on aphid biological control. Apparently, there was no strong complementarity or interference among predator species that altered the strength of aphid suppression. Instead, our experiments revealed strong effects of species identity, because predator species varied dramatically in their per-capita consumption rates. The implications of these results for conservation biological control and sustainable agriculture will be discussed.

WEST NILE VIRUS IN CALIFORNIA: APPLIED ENTOMOLOGY AT THE SHARP END OF THE SPEAR

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The introduction and subsequent expansion of West Nile virus into California was expected by an extensive organization of independent mosquito abatement districts (MADs) and county public health offices. For years, California MADs have monitored and treated the mosquitoes now responsible for transmission of WNV to humans, but formerly considered important as vectors of native viruses. It has been acknowledged that these efforts resulted in fewer human cases than would otherwise have been expected, particularly in southern California where the virus was abundant in birds and mosquitoes.

Local agencies responsible for their own geographic areas communicate with and accept direction from two interacting state organizations. One, the California Department of Health Services, oversees a gold-standard monitoring program and provides knowledgeable scientific advice. The other, the Mosquito and Vector Control Association of California, is a professional organization that is organized from the bottom up and acts as a valuable interface between local agencies and state government.

California's West Nile virus response was a success not only for the mosquito abatement industry, but also for an extremely extensive application of Integrated Pest Management (IPM). To some extent, the four steps of IPM (risk assessment, surveillance, integrated control, and monitoring) were extended to a cooperative relationship with public health assets. We might be able to think of this as "Integrated Disease Management," a concept that would benefit the community in many different contexts.

MANAGEMENT OF STORED-PRODUCT INSECTS IN FOOD-PROCESSING FACILITIES USING ELEVATED TEMPERATURES: ISSUES AND CHALLENGES

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The use of elevated temperatures, or heat treatments, is a viable alternative to methyl bromide fumigation for disinfesting food-processing facilities. The concept of heat treatment involves raising the ambient temperature of facilities using gas, electric, or steam heaters to 50-60^{o}C and maintaining these temperatures for 24-36 h. Heat treatment technology has been in existence since the early 1900s. The phase-out of methyl bromide due to environmental concerns has renewed interest in exploring heat treatment

technology as an alternative treatment. Although several food-processing companies use heat treatments at least one or twice a year, very little quantitative data are available on the amount of heat energy required to heat a facility, minimum temperature-time combinations needed for 100% mortality of economically important stored-product insects, and duration of effectiveness of heat treatments. Furthermore, very little is understood about the effects of high temperatures on the equipment and structures. This paper will summarize current knowledge about this technology, and issues and challenges that need to be addressed to make this an integral part of food-processing IPM programs.

OVERWINTERING OF THE CORN LEAFHOPPER AND CORN STUNT SPIROPLASMA IN THE SAN JOAQUIN VALLEY

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A study was conducted in California's southern San Joaquin Valley to determine the overwintering survival of the corn leafhopper, *Dalbulus maidis* and *Spiroplasma kunkelii* the causal agent of corn stunt disease. Corn leafhopper populations were sampled from November to March using yellow sticky cards, D-vac suction samples and inspection of volunteer corn plants and spring planted corn. *Spiroplasma kunkelii* presence was determined by sampling sentinel plants placed in the field during the winter, leafhoppers collected throughout the winter, evaluation of volunteer plants over the winter and spring planted corn. Leafhoppers were collected on yellow sticky cards throughout the winter during all 3 yr. They were regularly recovered from alfalfa, *Medicago sativa* , winter forage and riparian areas adjacent to stream courses by D-vac suction sampling. Females constituted the majority of leafhoppers (>80%) recovered on both sticky cards and from D-vac samples. *Spiroplasma kunkelii* was recovered from leafhoppers throughout the winter, from sentinel plants and in spring planted corn. Volunteer plants were a critical key in leafhopper overwintering and the survival of *S. kunkelii*. Volunteers extended the season by as much as 2 mo, thus shortening the period of time the leafhoppers were forced to go without a food source.

CONTROL OF WESTERN TARNISHED PLANT BUG (*LYGUS HESPERUS* KNIGHT) WITH ALFALFA TRAP CROPS IN CALIFORNIA ORGANIC STRAWBERRIES

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The western tarnished plant bug (WTPB), *Lygus hesperus* Knight, is the primary cosmetic pest in the organic strawberry production system in coastal Central California. WTPB feeds on the achenes ("seeds") of the developing strawberry fruit, causing the "fruit" (receptacle) to develop in an uneven, twisted, seedy, or "cat-faced" pattern. WTPB feeding can severely reduce berry size, weight, and marketable appearance and distorted fruit is rejected buy wholesale buyers and consumers. WTPB has a broad reported host range, with records indicating that it feeds on more than 100 host species in numerous families, including many winter broadleaved weeds in coastal Central California, such as wild radish, mustards, chickweed, lupine and other legumes, and knotweed. Non-crop host vegetation planted in association with a main crop theoretically can function as a sink ("trap") for WTPB if it is more attractive than the main crop. Previous research has established that WTPB is strongly attracted to alfalfa, and we hypothesized that alfalfa can be managed as a trap crop in organic strawberry production. In 2003 and 2004, completely randomized design trapping experiments were established in an organic strawberry field. Treatments consisted of (1) planting of an in-row alfalfa trap crop, vacuumed twice weekly with a tractor-mounted vacuum device (2) un-vacuumed in-row alfalfa trap crop (3) no trap crop, whole field vacuuming (grower's weekly program) (4) no trap crop, un-vacuumed (untreated) control. Results indicate that the vacuumed alfalfa trap crop treatment significantly reduced damage due to WTPB bug feeding in associated strawberry rows, compared with a weekly whole field vacuuming program and untreated controls. Treatment differences in WTPB densities and damage were recorded at a distance of up to 16 strawberry rows away from the trap crop. These results are important to organic strawberry growers because a trap crop-vacuuming program also resulted in a significant reduction in cost and machine-time effort expended when compared with the whole-field vacuuming treatment.

MONARCHS TAGGING: WHAT TAG RECOVERIES TELL US ABOUT THE MIGRATION

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Monarch tagging , in which small individually coded adhesive tags are applied to the wings of monarchs by thousands of volunteers each fall, has provided new information

on the dynamics of the migration. The numbers of monarchs tagged by volunteers has ranged from 40,000 to >100,000 for the last 9 years. Recovery rates of monarchs reaching Mexico range from approximately 0.5 to 3%, with higher recovery rates following winter the storms of 2002 and 2004. El Rosario, a site that hosts +/-40% of the total overwintering population, is the source of >80% of the tags. The records of 6800 monarchs recovered in Mexico have been analyzed. Within a relatively narrow longitudinal range from Minnesota through Texas, the rate of recovery is a function of distance. Recovery rates decline in a non-linear manner at longitudes east of the Midwest. Within the United States, a disproportionate number of the recoveries occur in the mid-Atlantic states. The date of tagging, across all latitudes, for all years, and of select years, shows that the migration progresses southward in a predictable pattern each year. Recovery rates are highest for monarchs tagged near the midpoint of the migration across all latitudes.

EVALUATION OF BAITS FOR CONTROL OF SUBTERRANEAN TERMITES (*RETICULITERMES* SPP.) UNDER WILDLAND CONDITIONS

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Baits are important tools for control of subterranean termites. They can eliminate entire populations of termites. To test baits, we established a 4-ha field site near Placerville, CA. We chose a wildland location to simplify logistics. We installed wooden stakes on a 2-m grid. Once fed upon by termites, independent monitoring stations (IMs) were installed adjacent to stakes. We monitored IMs monthly for termite activity and wood consumption; 12 IMs were selected that represent the demographics of one species. One or two additional IMs were installed near each occupied IM. Eight bait stations (BSs) were then installed at 1-m intervals in a 90º, radial pattern around the original IMs. We collected termite samples from all IMs and BSs to establish laboratory colonies, to conduct agonism assays, and to determine species of termites in each IM or BS. From these data we identified at least one IM and one BS, with termites from the same colony, for all 12 colonies. Half of the colonies were randomly assigned to the bait treatment and half assigned as controls. After baiting we will monitor IMs for termite activity and wood consumption to evaluate the decline of the colonies, and thus, bait efficacy.

MOTHS OF A NATIVE PALOUSE PRAIRIE

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Palouse prairie is a fragmented landscape that occurs in southeastern Washington, northwestern Idaho and northeastern Oregon. The prairie has been primarily converted to agricultural fields, grazing pastures and rural areas and, less than 1% that is still intact consists primarily of small, isolated plots of land that were not amenable to farming. Little is known about the moth fauna in native Palouse habitats. In our study we are conducting a survey of the moths found in native prairie habitats. A site approximately 3 miles NW of Colton, WA (Whitman Co.) was chosen for our study. Known as Kramer, this land has never been farmed or grazed. Kramer is approximately 15 ha, and is surrounded by wheat and lentil crops. We are surveying the area, by using 15-watt black light traps, mercury vapor lamps and by sweep netting. Results from the first field season of our study will be presented.

PATTERNS OF HABITAT USE BY OVERWINTERING MONARCHS (*DANAUS PLEXIPPUS*) IN MONTEREY COUNTY, CA

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Monarch butterflies (*Danaus plexippus*) in western North America overwinter on the coast of California in groves that fit specific environmental parameters. Overwintering sites must be able to buffer Monarchs from extremes of temperature, humidity, and wind, and are typically characterized by dense groves of trees forming natural amphitheaters. We began monitoring Monarchs and their overwintering habitats at eight Monterey County sites beginning in 2001. Three groves contained a variety of tree species, including Monterey pine (*Pinus radiata*), Coast redwood (*Sequoia sempervirens*), Monterey cypress (*Cupressus macrocarpa*), and *Eucalyptus spp*. Three groves were composed of Eucalyptus, and two were comprised of Monterey pines. We examined patterns in cluster formation including cluster height and aspect, and analyzed relationships between tree species use and regional climate variables. Average cluster height was 9.02 meters. Clusters most frequently had a Southeastern orientation. We used Spearman's Rank Correlation to elucidate an observed trend toward increased use of coniferous tree species after significant storm events. The percentage of butterflies found on coniferous trees exhibited a negative correlation with temperature. Correlations between tree species use and rainfall varied between sites and years. Neither humidity nor wind speed were correlated with tree species use. We recommend that future monitoring at these overwintering sites include the collection of microclimate data from each site. Continued population and habitat monitoring coupled with the implementation of adaptive management principles at each site will ensure the long-term preservation of overwintering Monarchs in central coastal California.

WEST NILE VIRUS SURVEILLANCE BASED ON DEAD BIRDS IN SANTA CLARA COUNTY - (WNV SYMPOSIUM)

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In 2004 about 252 dead birds were sampled for West Nile virus (WNV) in Santa Clara County. Detection of WNV was attempted from 31 bird species using the VecTest® antigen assay, PCR or sometimes both. The VecTest® yielded 23 WNV positive birds: 18 American crows and 5 Western scrub jays. There were 184 negatives using the VecTest® taken from 21 bird species, which included other corvids (raven, yellow billed magpie and Steller's Jay), raptors, house sparrows, etc . . .). PCR-based results (California Vector-Borne Disease Section) yielded 41 WNV positives birds from 9 species and 37 negative birds from 13 species. The "Dead Bird Program" is one component in the Santa Clara County Vector Control District's Integrated Pest Management Program. Surveillance and monitoring for WNV using dead birds depended upon public reports typically from residential zones. Three WNV positive birds were recovered as early as week 21 (May 17, 2004) and the peak month for positives (n=18) was August. The last WNV positive dead bird was a sparrow collected on week 49 (December 2nd). WNV positive raptors were detected in greatest numbers from July through August whereas, positive corvids were detected from May through October. Based on GIS, there appeared to be 2 foci in San Jose primarily composed of American crows and Western scrub jays. The distribution of positive raptors appeared to be more widely scattered along the western side of Silicon Valley. In 2004, it was interesting to note the absence of WNV positive birds collected from northeastern San Jose and Milpitas.

DEVELOPMENT OF A STRATEGY TO CONTROL THE FIELD ANT, *FORMICA PERPILOSA*, IN TABLE GRAPE VINEYARDS

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This study focuses on developing strategies to control the field ant, *Formica perpilosa* (wheeler) in table grape vineyards using low-toxic bait. I analyzed the spatial relationship among *F. perpilosa* nests within three vineyards located in the Coachella Valley (Riverside County, California). Vineyards were visually surveyed for ant nests and the data were analyzed using geostatistics. In addition I determined the average foraging range and territory of *F. perpilosa* colonies. Average foraging distance was determined by providing foraging ants with an attractive food source, and observing them returning to the nest. To determine the home range, ants were collected from different nests, placed in a Petri dish for a period of 5 minutes and observed for aggression. The geostatistical analysis showed that *F. perpilosa* populations were randomly distributed

within the vineyards. The behavioral assays showed a moderate level of aggression among colonies indicating that territories may overlap.

CURRENT DISTRIBUTION AND ABUNDANCE OF *CHAETORELLIA SUCCINEA* (COSTA) ON YELLOW STARTHISTLE IN SOUTHEASTERN WASHINGTON

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Biological control efforts targeting yellow starthistle, *Centaurea solstitialis* L., in North America have resulted in the introduction of seven seed head-infesting insects to date from the weed's native range. One of the most recently introduced bioagents, the false peacock fly, *Chaetorellia succinea* (Costa) (Diptera: Tephritidae), is the result of an unintentional release into Oregon in 1994. Since its introduction, studies have shown that this insect is a potentially important addition to the suite of organisms attacking yellow starthistle. However, current information regarding establishment and infestation levels of *C. succinea* in Washington, one of the states most heavily infested with yellow starthistle, is lacking. The purpose of this study is to identify the distribution and abundance of *C. succinea* in southeastern Washington where yellow starthistle is known to occur. Seed heads were collected from four sites (N, S, E, W) in each of eight counties in southeast Washington, along with information detailing various site characteristics. Relevant attributes of these sites recorded in attempt to aid in explaining the occurrences observed included yellow starthistle density, stand size, plant dominance, other agents present, land use, vegetation type, and soil type.

NOVEL INSECTICIDES AND PEST MANAGEMENT PROGRAMS IN VARIOUS AGRICULTURAL SYSTEMS

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Chemical control is an important component of integrated pest management systems. Insecticides with novel modes of action such as buprofezin, pyriproxyefen, spiromesifen, and various plant oils and extracts such as FACIN can be powerful tools for managing various whitefly species such as *Trialeurodes vaporariorum* and *Bemisia tabaci* and pysllids such as *Paratrioza cockerelli* in field and vegetable crops. Insecticides with unique modes of action are especially important considering whiteflies and pysllids have developed resistance or have tolerance to pyrethroid and organophosphate insecticides. Alternating these insecticides into a crop system in a defined way should reduce the potential risk of insect resistance to these insecticides and alleviate or delay the resistance problem for neonicotinoids, organophosphates, carbamates and pyrethroids. The

potential roles of the aforementioned insecticides in integrated pest management programs are discussed.

GLASSY-WINGED SHARPSHOOTER, *HOMALODISCA COAGULA* AND PIERCE'S DISEASE, *XYLELLA FASTIDIOSA*, PLANT INTERACTIONS

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Glassy-winged sharpshooter (GWSS) population dynamics on young (5 years) and old (20 years) orange trees and related biochemical mechanisms were investigated in a field experiment. The numbers of GWSS were much higher on the young trees compared to those on the old trees. Levels of xylem asparagines, glutamine, threonine, valine, phenylalanine, tyrosine, isoleucine, lysine, methionine, and histidine were also higher in the young trees in comparison with those in the old trees. These results suggest that particular amino acids play critical roles in GWSS host selection.

Xylem fluid of grapefruit, orange and lemon caused PD Temecula strain of X*f* cells to aggregate and form large white clumps but inhibited the attachment in glass culture tubes. In contrast, grape xylem fluid did not cause visible *Xf* cell clumping, but led to heavy attachment. Grapefruit xylem fluid significantly increased multiplication of *Xf* cells compared with grape xylem fluid. Citrus varieties, especially grapefruit, appear to be suitable hosts for *Xf* growth and may serve as a reservoir of the pathogen for GWSS acquisition and transmission to grape vines.

LIGHT RESPONSIVENESS IN HONEY BEES (*APIS MELLIFERA* L.)

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Honey bees are a model system for studying foraging behavior. Sensory responsiveness affects individual foraging behavior as well as the collective foraging decisions of entire honey bee colonies. Sucrose perception has been widely tested in honey bees using the Proboscis Extension Response (PER) test. A recently developed light assay allows the investigation of another sensory modality, vision. In these studies, wildtype foragers and preforager bees of selectively bred strains were tested and scored for their perception of several sucrose concentrations and light intensities. There were positive relationships between scores for these two sensory modalities. Wildtype pollen foragers had higher scores for responsiveness to sucrose and light than wildtype nonpollen foragers. Pollen foragers also responded more rapidly to lower intensities of light than nonpollen foragers. In the selectively bred bees, high strain preforagers had higher scores for both sucrose and light responsiveness than low strain preforagers. High strain bees responded to lower

intensities of light in less time than nonpollen foragers, but took more time to respond to higher intensities of light. These PER tests and light assays demonstrate a positive relationship between responses to light and sucrose with respect to foraging behavior and genotype.

THE DR. JEKYL AND MR. HYDE IN NEW "BIORATIONAL" INSECTICIDES FOR TREE FRUIT IPM

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We compared sublethal and acute mortality responses of 6 insect species, two parasitoids, *Colpoclypeus florus, Mastrus ridibundus* and four predators, *Anthocorus nemoralis, Chrysoperla carnea, Deraeocoris brevis, Forficula auriculsaria, Typhlodromus occodentalis*. Bioassays systems were developed for each species which included presentation of toxins topically, per os, and as residue simultaneously. Insect responses were measured for a core group of six insecticides which included 2 neo-nicotinoid insecticides, Provado and Assail, three IGRs, Intrepid, Esteem and Rimon, and the spinosad product Success. We show that moderate to severe and unexpected sublethal effects can occur with most products. Also we discuss problems of bioassay systems and comparison of sublethal effects for taxa with highly divergent life histories. Finally our results are re-presented using the common currency of reduction in net future reproduction estimated using Leslie matrix projection. The apparent fit of these products to biologically based IPM must be carefully considered on the impact of each key natural enemy.

GARDENS OF MULTIFLORAL ROSE ENHANCE BIOLOGICAL CONTROL OF PEST LEAFROLLERS IN POME FRUITS IN THE NORTHWEST

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Wild rose plantings are shown to enhance the parasitism of pest leafrollers, *Choristoneura rosaceana* and *Pandemis pyrusana*, by the parasitoid *Colpoclypeus florus* in adjacent organic and conventionally managed apple and pear orchards in Washington. The benefit of the habitat modification stems from the biology of the alternate host, the strawberry leafroller, *Ancylis comptana*, which occurs naturally on wild multifloral rose in parts of the Northwest. The leafroller overwinter as large larvae, a rare life history

strategy among leafrollers, and provides an abundant host suitable for over wintering of *C. florus*. High abundance of over wintering *C. florus* adjacent to orchards results in very significant spring parasitism and, in turn, elevated summer parasitism of pest leafrollers in the orchards. The key elements of this habitat modification are: 1) maintaining populations of the alternate non-pest host in the roses, 2) suitable size and placement of the rose gardens, and 3) prevent of disruption by pesticides of the activity of parasitoids both in the orchard and in the gardens. These reflect our current challenges in broadly expanding this sustainable approach viz reducing pesticide use and drift and preventing natural biological control from extirpating or dramatically reducing *Ancylis* populations in rose patches.

ORGANIC CONTROL MEASURES FOR OLIVE FRUIT FLY IN SMALL-SCALE ORCHARDS AND LANDSCAPES IN COASTAL CALIFORNIA

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The olive fruit fly (*Bactrocera oleae*) (OLFF) is a devastating pest for California's commercial table olive and olive oil industries, but also affects non-commercial landscape trees by ruining the fruit and creating a reservoir of insects that can infest commercial orchards. This trial compares the following organic treatment methods applied at 28 different sites in Sonoma County, California: Attract and Kill trap, McPhail trap, OLIPE trap, Yellow Sticky Panel trap, Kaolin Clay (Surround), and GF-120 (Spinosad - Naturalyte). Various attracting food baits and different brands of commercially available pheromone attractants were used with the traps. The best control achieved in our trials, based on damage levels at harvest, was with the use of two applications of Kaolin Clay (1.6% damage) followed by GF-120 (3.7% damage), Attract and Kill traps (13.6% damage), Yellow Sticky Panel traps (30.8 % damage), McPhail traps (33.2% damage), and OLIPE traps (33.4 to 65.7% damage). The untreated control trees had an average of 87.6% damage. As a monitoring tool the Yellow Panel and McPhail traps caught the most flies. There were mixed results with the use of pheromones as attractants.

INSECTICIDAL AND REPELLENT ACTIVITIES OF SELECTED MONOTERPENOIDS ON *AGRIOTES OBSCURUS* (COLEOPTERA: ELATERIDAE)

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Insecticidal and phytochemical toxicities were determined for four naturally occurring monoterpenoid essential oils on late instar larvae of *Agriotes obscurus* in laboratory and greenhouse bioassays. Both contact and volatile toxicities were determined for thymol, citronellal, eugenol and rosemary oil at the following concentrations: 100, 200, 400, 800 and 1600 µg/larva. Thymol had the greatest contact toxicity (LD_{50}=196.0 µg/larva) while citronellal and eugenol were significantly less toxic (LD_{50}=404.9 µg/larva and 516.5 µg/larva, respectively). Rosemary oil did not show any significant contact toxicity, regardless of concentration. In volatile bioassays, citronellal was the most toxic to wireworm larvae (LD_{50}=6.3 µg/cm^3) followed by rosemary oil (LD_{50}=15.7 µg/cm^3), thymol (LD_{50}=16.9 µg/cm^3), and eugenol (LD_{50}=20.8 µg/cm^3). Phytotoxicities and repellent activities were also evaluated using corn seed germination and development. In laboratory bioassays, thymol and citronellal significantly inhibited seed germination and development while rosemary oil had only minimal phytotoxic effects. Based on these laboratory results, four treatments were selected for greenhouse experiments: citronellal 400 µg, thymol 200 µg, rosemary oil 800 µg and eugenol 800 µg. Seeds treated with rosemary oil produced the highest number of distressed wireworms (56%, odds ratio = 2.64, p=0.000) compared to all other treatments while seeds treated with thymol had the least amount of feeding damage (9.3% damaged, odds ratio = 0.15, p=0.000). Rosemary oil, thymol and citronellal did not create any significant phytotoxic effects while eugenol significantly inhibited seed germination (25.3% germination, odds ratio=4.37, p=0.000). In conclusion, we found rosemary oil, thymol and citronellal posses both toxic and repellent effects against *A.obscurus* and should be further evaluated as natural alternatives to synthetic pesticides.

AREAWIDE II: IMPLEMENTATION OF NON-OP PEST MANAGEMENT PROGRAMS ON PEARS IN OREGON'S HOOD RIVER VALLEY

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Areawide II is a federally and grower-funded collaborative project to evaluate selective alternatives to organophosphate (OP) insecticides for control of codling moth and to enhance biological control in pear orchards. The study has been ongoing since 2001 and was limited initially to three commercial orchards in the Hood River Valley. In 2004, the

demonstration project was expanded to ten commercial pear orchards. Growers had to agree to use organophosphate (OP) alternatives for controlling codling moth and other pests. In return, growers were provided with information and advice about the status of major and minor pests, natural enemy activity, timing of sprays and whether pest levels justified control. Growers made their own decisions about what insecticide to apply. Monitoring information about pest and natural enemy populations was summarized weekly in a report for each grower and distributed electronically over the Internet. The weekly reports were intended as supplemental information for growers so they could make informed pest management decisions and respond to emerging problems in a timely manner. This project complemented the EPA-funded Best Management Practices Project to reduce broad-spectrum pesticides, especially OPs in surface water of the Hood River Valley and improve water quality (see symposium on 'Pesticides and Water Quality').

HOST RANGE OF *PERISTENUS* SPP. ATTACKING *LYGUS HESPERUS* IN WASHINGTON STATE, USA

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The Lygus bug, *Lygus hesperus* Knight (Hemiptera: Miridae), attack a broad range of host plants in Washington State including alfalfa, fruits, vegetables, seed crops, and numerous weedy plant species. The Washington State apple and alfalfa seed industries have identified Lygus as an insect pest in need of study. *Peristenus* spp. (Hymenoptera: Brachonidae) attack and consume the nymph stages of Lygus keeping individuals from reaching sexual maturity. Extensive surveys conducted in 2002, 2003, and 2004 determined the presence of Lygus parasitism by *Perisitenus* spp. in several important fruit and alfalfa seed production regions in Washington State. However, the results of the survey were disappointing in that levels of parasitism were low or not detected in several locations. We plan to present the significant findings from three years of efforts investigating the host range and relative abundance of *Peristenus* spp. attacking Lygus in and near Washington State tree fruit and field crops.

DESIGNING THE FOREST WITH THE TREES: QUANTITATIVE ASSESSMENT OF FOREST STRUCTURE FOR OVERWINTERING MONARCH BUTTERFLIES

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The monarch butterfly migration phenomenon is utterly dependent on a limited number of forested overwintering sites in Mexico and California. The forest canopy structure at these sites, no matter which species of tree(s), must provide proper microclimatic conditions during the overwintering season: minimal exposure to freezing temperatures,

protection from winds, and sufficient sunlight to allow for thermoregulation. This presentation describes detailed quantitative assessments of canopy structure using hemispherical photography, and derivation of temperature, wind, and sunlight exposure factors that can be mapped out at a fine scale. Assessments for short- and long-term management and restoration of sites are illustrated with *Eucalyptus* groves in Pacific Grove and Andrew Molera State Park, and initial results from Oyamel fir forests in Michoacan, Mexico. The habitat requirements for overwintering monarchs are understandable from a microclimatic viewpoint, and systematic, quantitative, and understandable assessments that allow for effective conservation of the phenomenon are feasible.

MEASURING, MONITORING, AND MITIGATING ENVIRONMENTAL RESIDUES OF PYRETHROID INSECTICIDES

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Pyrethroid insecticides are widely used in agricultural and residential pest control, but until recently there had been little or no environmental monitoring for these compounds. Analytical techniques are now available, but even so, the best analytical techniques are only barely able to detect acutely toxic concentrations to sensitive species, and are probably unable to detect chronically toxic concentrations. We have conducted extensive environmental monitoring in agricultural and urban areas, and these data will be summarized as to the frequency of pyrethroid detection in aquatic sediments, the specific pyrethroid compounds that are present, and their toxicity to aquatic invertebrates. Given that pyrethroids are highly particle-associated, this fact suggests mitigation practices could be quite effective in reducing off-site transport of the associated pesticides.

INTEGRATING NOVEL COMPOUNDS INTO MIDWEST TREE FRUIT PRODUCTION

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Humid Midwest tree fruit production is characterized by assemblages of up to 24 primary and 18 secondary arthropod pests in arguably the world's most complex production systems of over 724 beneficial, neutral and exotic arthropod species. These perennial systems can be severely disturbed with an array of pesticides, ground cover, canopy and soil manipulations. FQPA mediated loss of older compounds, resistance and market forces have propelled producers to adopt novel strategies, tactics and tools. Various "soft," OP-alternative, reduced risk and organic programs have been developed from

University test plots to on-farm trials with conventional and biointensive IPM as well as organic producers. Each program is being evaluated using criteria established from a functional ecology indexing system that assesses soil, primary producer and arthropod stability. Pograms include the use of naturalite, neonicotinoid, sodium channel blocker, juvenile hormone analog, chitin synthesis inhibitor, ecdysteroid agonist, as well as granulosis virus, *Beauveria bassiana*, *Bacillus thuringienis,* and in the future, nematodes. Producer adoption surveys show initial ready uptake, but strong, long-term cost-based reversion which have eroded the more stable functional ecosystems tested to date.

SURVEY OF PARASITISM OF THE ALFALFA WEEVIL COMPLEX IN CALIFORNIA ALFALFA

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The alfalfa weevil complex, comprised of the Egyptian alfalfa weevil (EAW), *Hypera brunneipennis* Boheman (Coleoptera: Curculionidae) and alfalfa weevil, *Hypera postica* Gyllenhal (Coleoptera: Curculionidae), is the most damaging arthropod complex in California alfalfa. Feeding by weevil larvae can cause severe defoliation in an alfalfa field, significantly reducing yields. Although the alfalfa weevil is well controlled with insecticides such as organophosphates and carbamates, the occurrence of insecticides in surface waters has placed added emphasis on finding alternative means to manage this pest. Biological control by parasitic Hymenoptera has been effective in reducing chemical applications against the *H. postica* in many other alfalfa-growing regions in the United States. Ten species of parasitoids were released as possible biological control agents from 1957-1988; three were reported as established or recovered from studies conducted by Pitcairn and Gutierrez (1989). Our study, conducted from February to June of 2004, focused on nine sites throughout California to sample for the presence of these previously released parasitoids. Three larval stage parasitoids, *Bathyplectes anurus* Thompson (Hymenoptera: Ichneumonidae), *B. curculionis* Thompson (Hymenoptera: Ichneumonidae) and *Tetrastichus (=Oomyzus) incertus* Ratzeburg (Hymenoptera: Eulophidae) have been recovered from our field sites, but overall percent parasitism appears to be low. In 2005, additional sites and sampling dates will be added to further assess parasitism levels.

URBAN BEE FAUNA AT THE BERKELEY OXFORD TRACT GARDEN

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Preliminary observations of native Californian bees visiting a decorative garden in Berkeley, CA prompted a more in-depth look at the likely diversity of native bees visiting potential habitats created in urban areas. The Oxford Tract Garden was planted in late 2003 with plants that were known to be attractive to native Californian bees. From the comprehensive study of this garden it was revealed that native bee diversity surpasses the originally estimated 25 species. It has also been noted that many bee species make use of this urban garden as a complete habitat with regard to feeding, mating, and nesting. Presented here is the diversity of bees found visiting the Oxford Tract Garden over the past two research seasons as well as an analysis of the quality of the constructed habitat with respect to promoting native bee diversity. This research has allowed for the creation of a database of fauna that serve to promote native Californian bees. The study continues into 2005 with special attention being paid to seasonal fluctuations in bee species and the development and natural succession of the constructed habitats.

DO BUMBLE BEES USE POLLEN ODOR TO DISCRIMINATE BETWEEN ROSA RUGOSA FLOWERS WITH DIFFERENT AMOUNTS OF POLLEN?

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Bumble bees can increase foraging efficiency by learning to recognize visual and olfactory floral cues that indicate the availability of nectar and/or pollen. It has been shown that in some instances bumble bees can use visual cues to distinguish between flowers differing in age or amount of food reward, but little is known on whether they use olfactory cues, particularly pollen odor, as well. The rose species, *Rosa rugosa,* offers pollen as a sole food reward, and the pollen has an odor that is chemically distinct from the rest of the flower. The goal of this study was to determine if bumble bees foraging for pollen on *R. rugosa* can discriminate between individual flowers that contain different amounts of pollen. Three different behavioral experiments were carried out in Sweden, in which free flying bees were offered an array of five pollen-rich and five pollen-poor flowers, with the pollen levels and time of day different between experiments. For each experiment, bumble bee responses to the flowers (approaches, landings, and pollen gathering bouts) were recorded in 15 separate 15-minute test trials that were conducted on different days. The data for 2004, an exceptionally cool summer, show discrimination by bees in some subsets of some experiments but none in others, whereas a similar study in 2003 gave a stronger indication that bees distinguish between flowers containing

different amounts of pollen based on pollen odor. The contrast in findings between the two years may be due to environmental conditions prevailing during the studies, which affected both pollen levels in the flowers and bumble bee foraging behavior.

TRANSMISSION PROFILES OF CALIFORNIA *CITRUS TRISTEZA VIRUS* ISOLATES BY THE COTTON APHID, *APHIS GOSSYPII*

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Aphis gossypii is the principal vector of *Citrus tristeza virus* (CTV) in California. Based on host range, a population of *A. gosspyii* exists as the melon aphid (MA) or the cotton aphid (CA) biotype. Previous reports on CTV transmission used the MA reared on cucurbits. The objective of this study was to determine CTV transmissibility by the CA. The CA was collected near Sanger on cotton and reared on cotton. The MA was collected near Reedley on squash and reared on squash. In reciprocal host tests, the CA did not survive on squash while the MA did survive on cotton. CTV isolates from field infected citrus trees from plots in Tulare and Kern Counties were established in Madam Vinous (MV) seedlings in the greenhouse. Vector acquisition of CTV was conducted on young infected shoots of MV. Inoculation of CTV was conducted on young Mexican lime shoots using 5 to10 `viruliferous' aphids per plant. The CA transmitted CTV isolates with a higher efficiency than did the MA. Using the CA, the CTV isolates fell into three stable transmission profiles: low (0 to 5%); intermediate (7% to 24%); and high (30% to 60%). Significantly more CTV isolates collected from a Kern Co. site had high transmission profiles than isolates collected from a Tulare Co. site.

MORTALITY OF CEREAL LEAF BEETLE IN COMPRESSED HAY EXPORTS

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Bale compression was investigated as a quarantine treatment to control cereal leaf beetle, *Oulema melanopus* (L.), in large-size bales of exported hay. Adults were collected on cultivated oats near Banks, Oregon, July 2004. The insects (n = 2,512) were placed in each of two pockets of a fabric bag (20 cm wide by 30 cm long) that was lowered into the compression chamber of the baler. The chamber was filled with chopped timothy hay, compressed (32 kg/cm² of pressure) into large bales (120 cm wide by 120 cm long by 78 cm high), and wrapped with polypropylene fabric. Five bales with eight fabric bags per bale were prepared in this manner. The fabric bags containing cereal leaf beetle adults were recovered from the bales after compression and immediately evaluated for survival.

No adults survived the large-bale compression procedure. Adult survival (n = 353) in non-compressed controls was 98.3%. Compression alone was found to be an efficacious treatment to control large numbers of cereal leaf beetle adults introduced into large-size, polypropylene fabric-wrapped bales.

BIG BALE COMPRESSION FOR CONTROL OF HESSIAN FLY IN EXPORTED HAY

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Quarantine strategies were developed to control Hessian fly, *Mayetiola destructor* (Say), in hay exported to Japan and other countries in the Pacific Rim. Hessian fly was reared on wheat seedlings (n = 15,215) to the puparial stage, harvested, and placed into each of two pockets of fabric bags (120 cm wide by 120 cm long by 78 cm high) (n = 48). The infested wheat seedlings were transported to Ellensburg, Washington, April 2004 to determine the effect of compression on insect survival using a new baling technique. The infested wheat seedlings in fabric bags were placed in the baler compression chamber (32 kg/cm² of pressure) with chopped timothy hay, compressed into large bales (120 cm wide by 120 cm long by 78 cm high), and wrapped with polypropylene fabric. The compressed wheat seedlings were recovered from the bales and immediately returned to the laboratory in Parlier, CA, and placed on moist vermiculite for evaluation of survival for 83 d. The total number of Hessian fly puparia (n = 24,344) tested was determined from adult emergence from controls (1.6 puparia per plant) not exposed to compression, and 3.0% of the total number survived bale compression. Compression alone was found to be an efficacious treatment to control large numbers of Hessian fly puparia introduced into large-size, polypropylene fabric-wrapped bales.

PATHOGEN-INDUCED HORMESIS IN THE BANANA APHID, *PENTALONIA NIGRONERVOSA* (HEMIPTERA: APHIDIDAE)

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Paecilomyces fumosoroseus is a hyphomycetous fungus showing potential as a biocontrol agent on certain homopterous insects. A local (Hawai'i) isolate of *P. fumosoroseus* was used in bioassays against the banana aphid *Pentalonia nigronervosa* Coq. The banana aphid is the vector of banana bunchy top disease, a severe affliction of bananas, and we hoped to find a local pathogen that might contribute to reducing aphid numbers and dispersal in banana plantations.

Dose-response assays were done using three different concentrations of the fungus; 10^6, 10^7 and 10^8 spores per ml and a control. No significant mortality occurred over a seven – ten day period following treatments. Inoculated aphids produced greater numbers of offspring compared to the control. The 10^6 and 10^7 treatments had the highest increase in numbers of aphids. There was a rapid increase in reproductive rate the first day after treatment. Mean increase in number of progeny per day was lowest in the controls and the 10^8 treatment. This appears to be a case of hormesis, induced by subjecting the aphids to doses of a sub-lethal stressor, in this case a fungal pathogen. The implications of this interaction with respect to pest status and biocontrol of banana aphids will be discussed.

MITIGATING ORGANOPHOSPHATE DORMENT SPRAY RUNOFF FROM ORCHARDS USING ALTERNATIVE MANAGEMENT PRACTICES

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Organophosphate insecticides, especially diazinon and chlorpyrifos, have been routinely detected in the Sacramento and San Joaquin River watersheds coincident with storm events which follow their application to dormant orchards. An interdisciplinary team has evaluated a number of mitigation measures that could be implemented by orchard growers to reduce the off-site movement of pesticides used during the winter dormant season. Field studies were conducted in subplots within commercial orchards where autosamplers collected rainfall runoff. Among hypotheses tested include 1) Orchard floor vegetation and other site management practices improves pesticide infiltration and decreases surface runoff from orchards; 2) Pesticide application timing influences the amount of residual pesticide that moves off-site with subsequent rain events; 3) Vegetated buffer strips reduce the toxicity of runoff; 4) Post spray sprinkler irrigation results in pesticide infiltration reducing toxicity of runoff.

Results of these studies indicate that site management practices can greatly influence off-site movement and toxicity of organophosphates which can affect nontarget aquatic species. Used in conjunction with alternative management of insect pests targeted by the dormant season organophosphate sprays and improved pesticide management practices, California growers can both achieve acceptable pest control and address environmental concerns.

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PAPER Submitted 10 minute Paper
SC-MS Student Comp. Paper (M.S.)
SC-PHD Student Comp. Paper (Ph.D.)
POSTER Submitted Poster Display
DSC-MS Student Comp. Poster Display (M.S.)
DSC-PHD Student Comp. Poster Display (Ph.D.)
SYMP Symposium Presentation
AWARD Woodworth or Comstock Award Winner