Presentations Day 1

Course Schedule

Time	Activity Type	Title
Morning Session		
8:00	Introduction	Welcome and Overview of Course
8:30	Presentation	General Overview and Introduction to Biological Control (BC)
9:10	Presentation	Principles of Pest/NE Interactions
9:50		**Break**
10:10	Presentation	Key Natural Enemy Groups: Life histories and peast control
10:45	Exercise	Identification of Key BC Agents
11:35	Review	Review of morning session with Q&As
12:00		**Lunch**
Afternoon Session		
1:00	Presentation	Natural Enemy Monitoring
1:25	Presentation	Natural Enemy Phenology
2:00	Presentation	BC Resources on the Web
2:25	Exercise	Windows of Opportunity
2:55		**Break**
3:15	Presentation	Effects of Pesticides on Natural Enemies
3:55	Exercise	***Case Study #1:*** Secondary Pest Problems – Why did they get out of control?
4:30	Review	Review of afternoon session with Q&As
4:55	Reception	**Social Hour and Poster Session of Day 1 Topics**
6:00		End of Day1 – dinner on your own

Presentation 1: Overview & Introduction to BC

General Overview and Introduction to Biological Control

Nick Mills, University of California, Berkeley
Vince Jones, Washington State University, Wenatchee

Notes:

Overview

- What is biological control and how can we implement it?
- What are natural enemies and why should we be interested in biological control?
- What is the role of biological control in IPM?
- What is the significance to current IPM in western orchards?
- How to enhancing biological control in western orchards?

Notes:

Approaches to Pest Management

Cultural
manipulation of the crop environment to reduce susceptibility to pests

Chemical
use of natural or synthetic pesticides

Biological
manipulation of pests or natural enemies to reduce damage

Notes:

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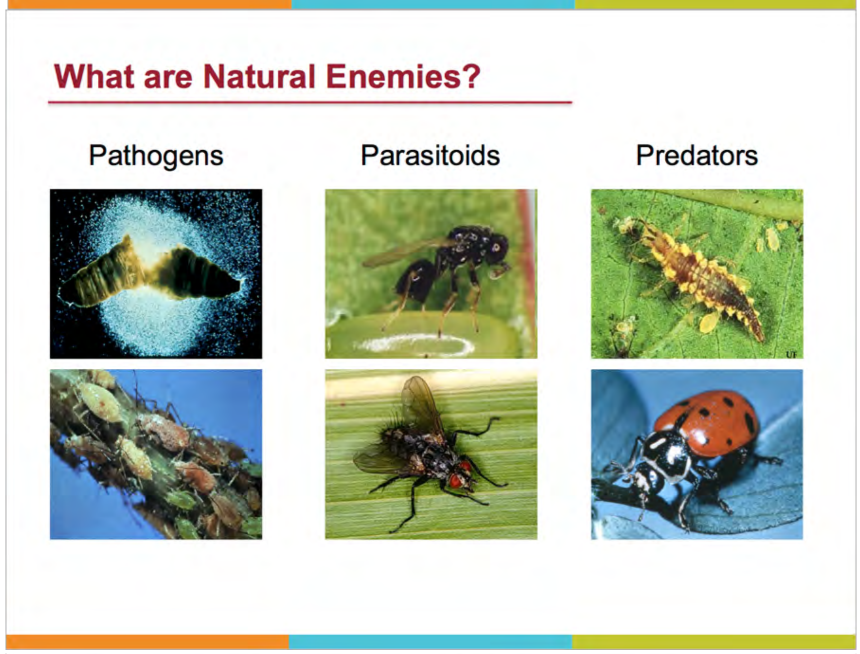


(Video on predators)

Notes:

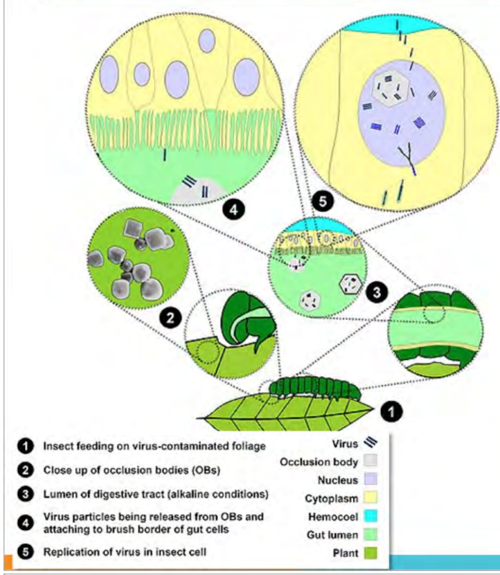
(Video on parasitoids)

Natural Enemies in Action: Parasitoid

Courtesy of Prof. Urs Wyss, Kiel University – Entofilms.com

Notes:

Natural Enemies in Action: Pathogen



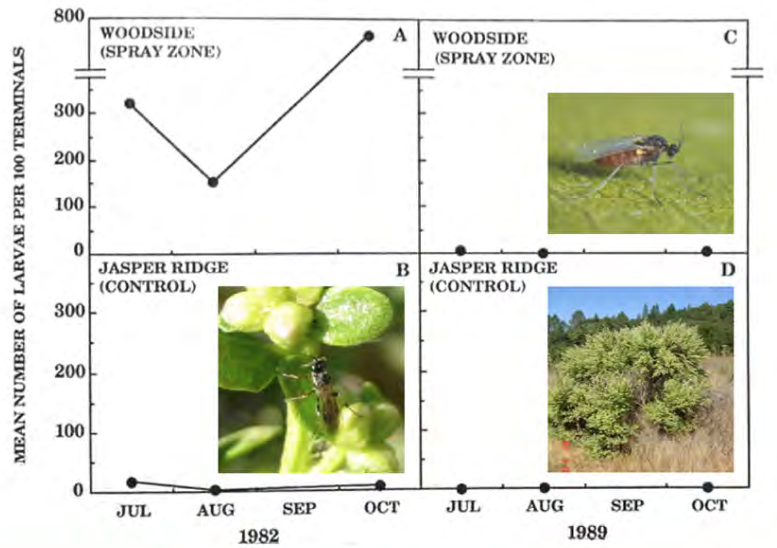
Notes:

Naturally-Occurring Biological Control

- Naturally-occurring biological control is present everywhere, but only detectable when disrupted
- Evidence for natural biological control in San Francisco East Bay during eradication of Med Fly 1981/82

Notes:

Notes:



Notes:

Applied Biological Control

Importation – import and establish specialized natural enemies from the region of origin of an invasive pest

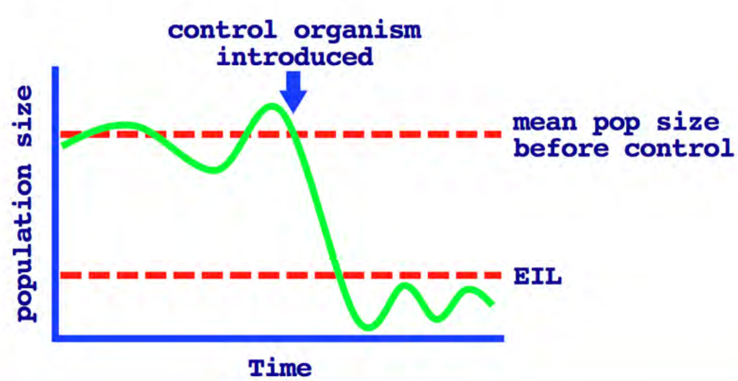
Augmentation – localized release of purchased natural enemies

Conservation – enhance the activity of natural enemies through modification of the crop environment

Notes:

Importation Biological Control

- Importation involves the use of specialized natural enemies from the region of origin of an invasive pest to reduce damage to a tolerable level



Importation Biological Control

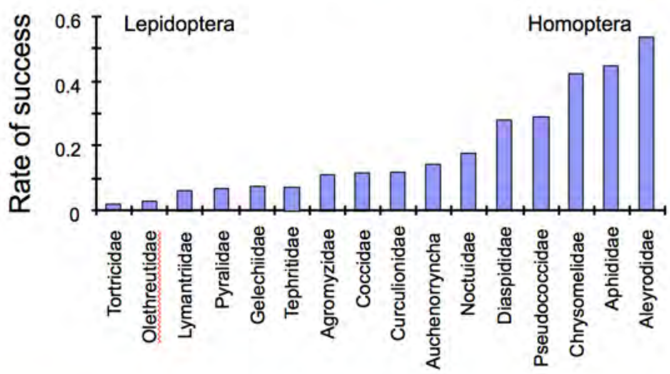
- Used against invasive pests only

- A public good exercise supported by governments, not implementable by growers or industry
- Outcome, if successful, is long-term sustainable control

Notes:

Importation Biological Control

- Variable success rates against different pest taxa



Patterns in CBC – Pest Taxonomy; Mills (2000)

Notes:

Augmentation Biological Control

- When natural enemies are not present, some species can be augmented locally through inoculation or inundation
- **Inoculation** is often used early season to overcome the delay in colonization of crops by natural enemies, where turnover from small releases provides season-long control
- **Inundation** is used at any stage of the season, where large releases of mass reared enemies provide immediate kill (biological pesticide) without persistence or turnover

Notes:

Notes:

Inundative Biological Control

- Natural enemies have been mass produced for over 80 years for use in pest management
- Results are often variable – sometimes used without even monitoring the impact
- What is the technical effectiveness of the selected natural enemy and can it be improved?
- Is mass production commercially viable? – advantage for some microbial products

Notes:

Inundative Biological Control

➢**Limitations due to Ecology and Application**

Ecology

- Match natural enemy to:
  - habitat (vertical stratification)
  - pest (preference)
  - climate
- Presence of intraguild predators

Application

- Commercial viability – market, cost
- Technical effectiveness – quality and persistence
- Dose-response curve – upper asymptote
- Ease of use – shelf life, duration of activity, delivery

Notes:

Conservation Biological Control

Two General Approaches

- Natural enemies limited by low tolerance of broad spectrum pesticides – conservation tactics include use of selective pesticides
- Natural enemies limited by lack of resources such as nectar and overwintering hosts – conservation tactics include floral subsidies and alternative hosts

Conservation Biological Control

Selective Pesticides

- New low risk insecticides that are replacing OPs are not always more selective with respect to natural enemies
- To enhance biological control we need to understand the selectivity of new classes of pesticides and periods of the season when key natural enemies are most active

Notes:

Conservation Biological Control

Floral Resources

- Lettuce aphids in California are managed by planting alyssum as a food supplement for syrphid predators

Notes:

Examples of Successful Applied Biological Control

- Western orchards provide some excellent examples of biological control that are often forgotten due to their continued success
- Such successes are providing natural pest control services to our orchard crops at no cost
- Failure to recognize these successes can lead to loss of control and an apparent need for increased insecticide usage

Washington State University World Class. Face to Face. | ars Agricultural Research Service | Oregon State University OSU | Berkeley University of California

Notes:

Notes:

Examples of Importation Biological Control

- Vedalia beetle imported from Australia for control of cottony cushion scale in California citrus in 1889
- First well-documented example of successful natural enemy importation worldwide


Notes:

Examples of Importation Biological Control

- Walnut aphid was a key pest of walnut production in CA in 1950s
- *Trioxys pallidus* was introduced from Iran in 1969
- Parasitism has provided sustained control of walnut aphid for > 40 yrs



Notes:

Examples of Augmentative Biological Control

- Fillmore Insectary, grower cooperative, produced *Aphytis melinus* for control of California red scale
- Served 250 growers and 8,000 acres of citrus
- 5,200 parasitoids/acre every 2 weeks from Feb to Aug
- Commercial success due to technical effectiveness and ease of use



Examples of Augmentative Biological Control

- Syngenta BioLine produces *Phytoseiulus persimilis* for control of two-spotted spider mites in strawberries in California
- Used on 50-75% of the 22,000 acres of strawberry in 1990s
- 10-10,000 *P. persimilis*/acre applied early season when spider mites pops. are low
- Commercial success due to technical effectiveness and ease of use


Notes:

Examples of Conservation Biological Control

- Strawberry leafroller infested roses can be an important overwintering site for the gregarious ectoparasitoid *Colpoclpeus florus*
- Parasitism of sentinel OBLR larvae approached 100% in WA apple orchards with adjacent patches of infested roses

Notes:

Examples of Conservation Biological Control

- Spider mites usually under effective biological control in western region by *Galendromus occidentalis*
- Stan Hoyt demonstrated that OPs, certain fungicides, and miticides disrupted BC causing mite outbreaks in 1960s
- Use of selective insecticides, lower dosages, improved timing restored BC by *Galendromus*


Notes:

Notes:

Biological Control – Evaluating Benefits

- Public good activity
- Reduces need for insecticide intervention
- Reduces risk of farm worker health issues
- Reduces risk of environmental pollution
- Preserves food, water and air quality

Notes:

Biological Control – Economic Benefits

- Annual benefit of walnut aphid control by *Trioxys pallidus* estimated to be $1.5 million
- Benefit to cost ratio of importation biological control estimated to vary from 15 to12,700
- Benefit to cost ratio of augmentative biological control estimated at 3 to 31
- Annual benefit of conserving predatory mites in apples is estimated to be $3 million

Notes:

Summary

- Biological control is an economically valuable and naturally occurring pest control service provided by natural enemies that can play a pivotal role in the IPM of arthropod pests
- Natural enemies can be effectively manipulated to enhance BC through classical introduction (invasive pests only), augmentation and conservation

Summary

- Classical introductions of exotic natural enemies have proved dramatic long term successes in the BC of some types of invasive pests
- Conservation of NE activity through selective choice and use of pesticides provides an opportunity for sustainable pest management in western orchards with significant economic and environmental benefits

Notes:

Principles of Pest/Natural Enemy Interactions

Vince Jones, Nick Mills, Andrea Bixby-Brosi

Presentation 2: Principles of Pest/NE Interactions

Notes:

Overview

- Why is now the time for BC
- NE habitat and resource needs
- Predator/Prey Searching
- BC as a component in IPM
- BC in organic & conventional systems
- Summary

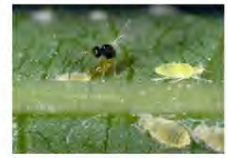
Notes:

Notes:

Why BC now?

Loss of Guthion…..

- Used for 50+ years
  - Trial and error gave simple, stable IPM
- Many NE were resistant to it
  - Western Orchard Predatory mite
  - Parasitoid of western tentiform leafminer
  - *Trioxys pallidus* (walnut aphid parasitoid)
- Provided broad spectrum suppression of a number of 2° pests



Notes:

Why BC now?

Registration of OP alternatives

- Many different modes of action
- Resistance management for pests will disrupt NE developing resistance
- Effects on NE poorly known
  - Timing
  - Residual activity longer
  - Sub-lethal effects on reproduction/survival

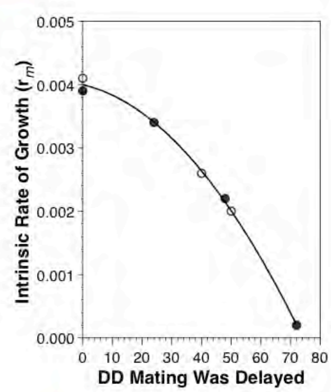
Actara, DuPont™ Altacor®, Assail 70WP, DuPont™ Avaunt®, BELAY Insecticide, BELT, calypso, CYAZYPYR, CLUTCH Insecticide, Delegate WG, Entrust Naturalyte, Proclaim, Rimon 0.83EC, Esteem, Intrepid 2F, PROVADO 1.6, Success 480 SC

Notes:

Why BC now?

Mating disruption…

- Highly specific and only affects CM
- Makes it hard for males to find mate
  - Delay in mating reduces reproductive rate
- Acts on a DD basis
  - Works best in hot times of year
- Affects all generations
- When used as the basis for IPM in apple, pear and walnut makes all control efforts better



Why BC now?

Future possibilities?

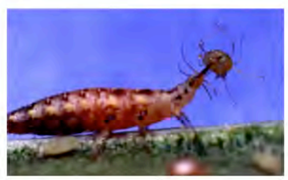
- "Pesticide replacement therapy"
  - Much more costly!
  - More problems with secondary pests
  - MRL issues for pome and stone fruits
  - "Toxic 12"
- Ecologically based IPM focused on BC
  - More information intensive
  - More stable, fewer 2° pest issues

Notes:

NE needs

Basic information on NE/Pests

- Predators
  - Typically free-living
  - Loosely association any prey stage
  - Many are generalists with multiple prey
  - Multiple prey items needed during life
- Parasitoids
  - Requires and kills only one host
  - One stage rigidly associated with host
  - May be responsible for killing many hosts
  - Both generalists and specialists
  - Female may host feed, killing many hosts

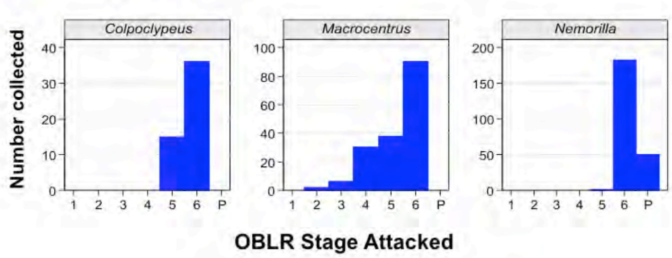


Notes:

NE needs

Synchrony with host/prey

- A parasitoid often attacks a specific stage
- Stage attacked varies considerably between parasitoid spp.
  - Parasitoids of adult insects are relatively rare
  - Egg, larval, pupal parasitoids are common

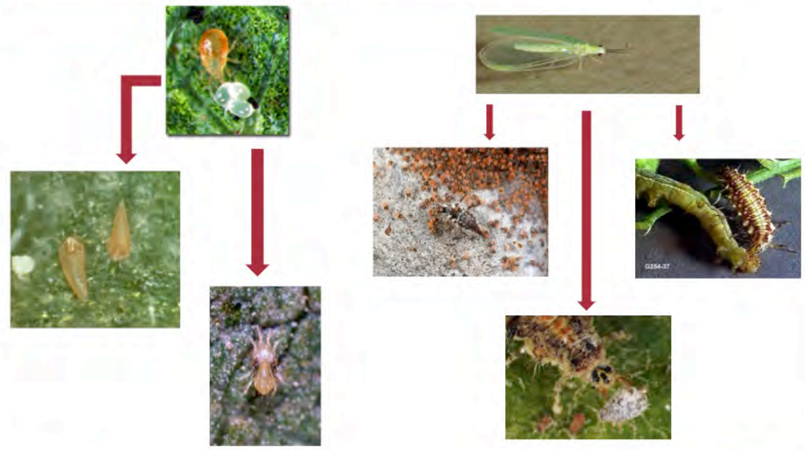


Notes:

Notes:

NE needs

Example alternate prey w/in orchard

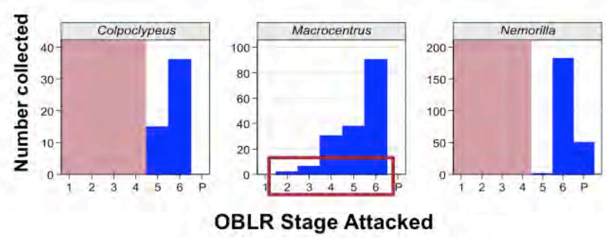


Notes:

NE needs

Overwintering /Extra-orchard hosts

- May need a different host to overwinter
- OBLR and PLR overwinter as instars 1-2
- Need synchrony of hosts/parasitoids

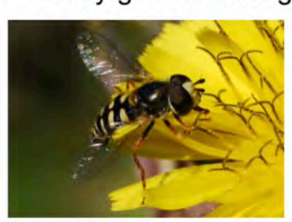


Notes:

NE needs

Nectar sources

- Adult stages may feed on pollen or nectar
- Increases longevity
- Increases reproduction
- May get NE through times w/ low prey/host density



Predator specificity

- Many predators are generalist feeders
  - May switch prey depending on abundance
- Tend to be important as general mortality factor of a number of pests
  - May not be able to regulate the pest
- Hard to quantify predator importance because they generally leave no trace
  - Requires direct observation
  - Molecular gut content analysis
  - Analysis of population dynamics

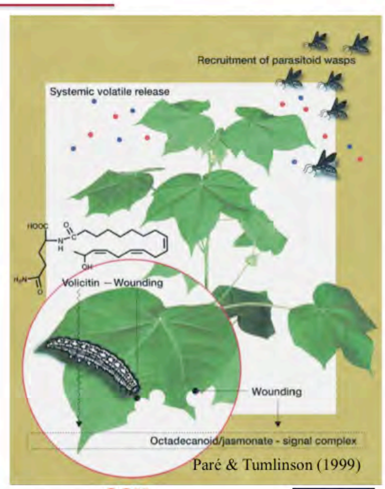
Notes:

Specific Predators

Notes:

How parasitoids find host

- Host habitat finding
  - Long-range volatiles
  - Visual silhouette
- Host finding
  - Herbivore-Induced Plant Volatiles (HIPV)
  - Sign of prey presence
- Host Acceptance
- Host Suitability



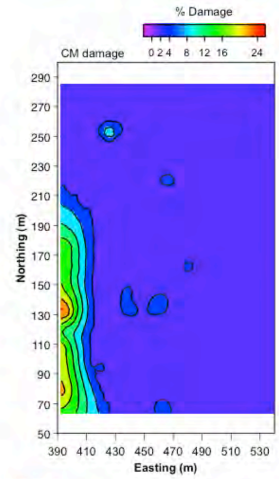
Notes:

Notes:

Predator/Parasitoid Searching

HIPV's and Host/Prey Search

- Distribution of pests:
  - Clumped at lower densities
  - Broadly distributed at high density
- Damaged areas = HIPV's release area
- Low density
  - HIPVs concentrate search
  - Dramatically improve efficiency
- High density
  - HIPVs are everywhere, not big help



Notes:

Predator/Parasitoid Searching

Host-Associated Cues

- Fecal matter
- Wing Scales
- Webbing for those that use silk
  - Leafrollers, spider mites
- Alarm pheromones of host
  - Aphids
- Substrate born vibrations
- Activity when probed

Notes:

BC as a component in apple, pear, walnut IPM

- BC will not control CM by itself
- Important to incorporate MD
- Biggest Benefits of BC:
  - 2° pest suppression
  - Improved worker safety
  - Lower residues in final product
  - Reduced environmental impacts
  - More stable IPM programs

Organic versus Conventional Systems and BC

- Both organic and conv. IPM can produce high quality fruit
- How are these systems different?

Factor	Organic Pesticide	Conventional Pesticide
Intensity of Mortality	↓	↑
Duration of Mortality	↓	↑
No. Times Applied	↑	↓
Importance of NE complex	↑	↓

- ***Does the organic way of applying mortality lead to less impact on NE and greater stability?***

Notes:

Can we mimic the organic approach?

- Dose makes the toxin

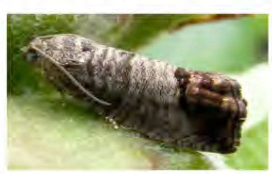
Factor	Organic	Low dose Conventional	Conventional
Intensity of Mortality	↓	↓	↑
Duration of Mortality	↓	↓	↑
No. Times Applied	↑	↑	↓
NE complex	↑	↑	↓
Cost	↑	↓↓↓↓	↓
Residues	↓	↓↓↓↓	↑
Restrictions on production	↑	↓	↓

- Low dose strategy (= physiological selectivity)
  - ***Basis for Integrated mite management***

Notes:

Won't this increase resistance problems?

- **NOOOOOOOOO!**
- Resistance is driven by selection pressure
  - Duration and intensity of mortality factor
- Increased BC reduces selection for resistance
- MD is 1° CM control method
  - Reduces selection pressure on pesticide



Notes:

Notes:

BC in conventional/organic

Evaluate low dose strategy

- 15 acres organic apples at WSU-Sunrise
- Sprays in first CM gen only
- MD across entire block
- One oil spray on entire block at 200 DD
- Break into 12 plots
  - 4 continue using organic control
    - Virus – 4x, (+10 days after oil (300 DD), then ≈ 10 d intervals)
  - 4 plots Delegate at 10% field rate
    - 4 x same time as organic
  - 4 plots Delegate at full rate
    - 2 x – +10 d from oil, +14 days (432 DD))

Notes:

BC in conventional/organic

Does low dose strategy work?

- So far no differences in damage by:
  - CM
  - Leafrollers
  - Spider mites
  - San Jose Scale
  - Aphids (WAA, GAA, RAA)
- Will continue for 3 more years
  - Also monitoring NE diversity/abundance
- Comparing 4 pairs of organic/conventional orchards for damage, NE diversity/ abundance

Notes:

Summary

- Transition period for IPM
  - Focus on incorporating BC
  - MD needs to be core for apple, pear, walnuts
- More information intensive
  - Understand NE needs and phenology
    - Alternate hosts, Nectar sources
  - Need better info transfer
- Protect NE from pesticides
  - Space
  - Time
  - Dose/Toxicant selection

Presentation 3: Key Natural Enemy Groups

Key Natural Enemy Groups: Life Histories and Pests Controlled

Nick Mills, UC Berkeley
Dave Horton, USDA-ARS, Wapato

Notes:

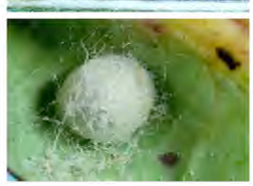
Predators – Lacewing groups

- Green lacewings (Chrysopidae)*Chrysoperla* *Chrysopa*
- Brown lacewings (Hemerobiidae) *Hemerobius*

Notes:

Predators – Lacewing biology

- Eggs protected on stalks
- *Chrysoperla* predatory as larva only
- *Chrysopa* predatory as adult and larva
- Larvae with hollow mandibles – extra-oral digestion
- Pupate in cocoons in curled leaves
- Parasitized as eggs, larvae and cocoons



Notes:

Notes:

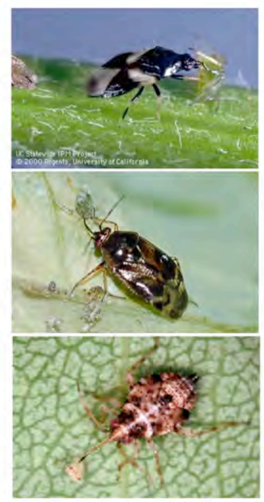
Predators – Lacewing prey

- Aphids
- Moth eggs/ young larvae
- Mealybugs
- Pear psylla
- Spider mites

Notes:

Predators – True bug groups

- Pirate bugs (Anthocoridae)
  Anthocoris and *Orius*
- Capsid bugs (Miridae)
  Deraeocoris and *Phytocoris*
- Assassin bugs (Reduviidae)
  Zelus



Notes:

Predators – True bug biology

- Predatory as adults and nymphs
- Eggs laid into plant tissue
- Piercing rostrum used to attack prey
- Seldom parasitized

Predators – True bug prey

- Pear psylla
- Aphids
- Scale insects
- Spider mites

Notes:

Predators – Ladybird beetles (Coccinellidae)

- Aphid feeders
  Coccinella, Hippodamia, Olla
- Scale feeders
  Chilocorus, Hyperaspis
- Spider mite feeders
  Stethorus

Notes:

Predators – Ladybird beetle life history

- Predatory as adults and larvae
- Eggs usually laid in batches
- Chewing mouthparts
- Pupate on foliage
- Parasitized as adults and pupae

Notes:

Notes:

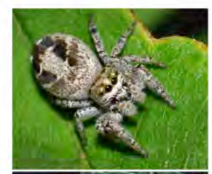
Predators – Hoverflies (Syrphidae) and life history

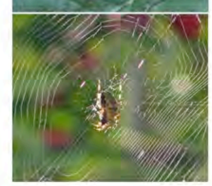
- Aphid feeders
  Eupeodes, *Scaeva*, *Syrphus*
- Predatory as larvae only
- White eggs laid singly
- Rasping mouthparts
- Pupate within curled leaves
- Often parasitized as larvae and puparia

Notes:

Predators – Spiders and life history

- Jumping spiders (Salticidae)
  Pelegrina, *Phidippus*, *Sassacus*
- Webbing spiders
  Dictyna, *Theridion*
- Single generation a year
- Feed less frequently than insect predators
- Hunt for, trap, or pounce on prey

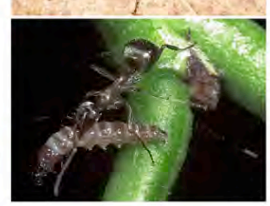




Notes:

Predators – Other groups

- Ground beetles (Carabidae)
  Pterostichus
  - Adults feed on ground at night
  - Larvae predatory in soil
  - Predators of moth larvae
- Ants (Formicidae)
  Formica
  - Ubiquitous, foraging as adults only
  - Many different types of insect prey
  - Farm honeydew producers and may damage nuts



Parasitoids of Moth Pests

- Ichneumonidae

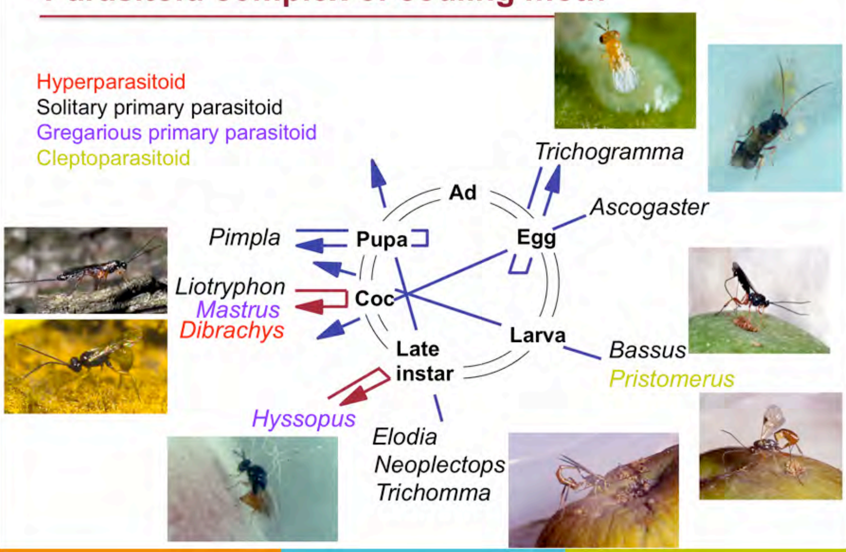
- Braconidae

- Chalcidoidea

- Tachinidae

Notes:

Parasitoid complex of codling moth



Notes:

Parasitoids of Aphids

- Braconidae (Aphidiinae)

  Aphidius, *Ephedrus*, *Lysiphlebus*, *Trioxys*

- Aphelinidae

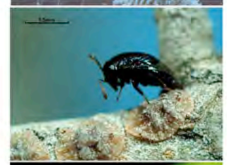
  Aphelinus

Notes:

Notes:

Parasitoids of Scale Insects and Mealybugs

- Encyrtidae
  Anagyrus, Leptomastix
- Pteromalidae
  Scutellista
- Aphelinidae
  Aphytis

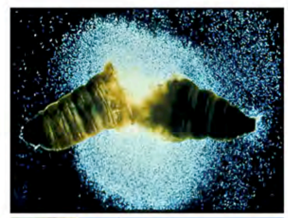


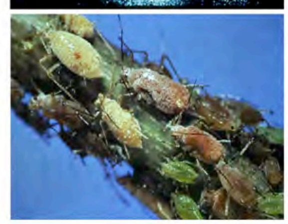
Notes:

Parasites and pathogens

- Entomopathogenic nematodes
- Bacteria
- Viruses
- Fungi

Presentation tomorrow on use of NPV's, Bt, and nematodes





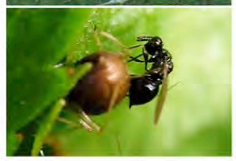
Notes:

Characteristics of Predation vs Parasitism

	Predator	Parasitoid
• Numbers consumed:	Many	One
• Physiological linkage:	None	Intimate
• Specificity	Low	High
• Foraging stage:	Juvenile + adult	Adult only

Forms of Parasitism

- Solitary versus gregarious
- Ecto- versus endo-parasitism
- Primary versus hyperparasitism



Notes:

Parasitoid life styles

➢ Endoparasitoids that allow the host to continue to feed and develop after attack

- Develop slowly from smaller eggs
- No host feeding
- Higher fecundity
- More specialized in host range

Notes:

Predator life styles (in orchards)

- Predation in larval stage only
  Chrysoperla, Hoverflies
- Predation in adult stage only
  Soldier beetles
- Predation in both juvenile and adult stages
  Ladybird beetles, *Chrysopa*, true bugs

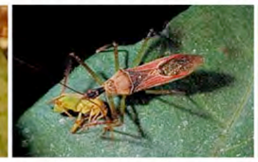
Notes:

Notes:

Predator life styles

- *Cannibalism*:
  feed on other individuals of the same species


- *Intraguild predation*:
  feed on other species of natural enemy

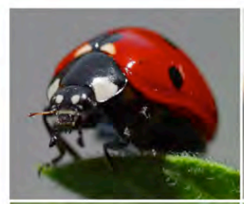



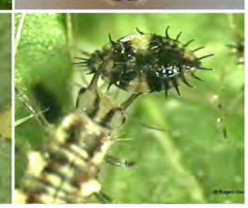

Notes:

Predator life styles

- Chewing mouthparts
  No remains of prey
  Feeding time short

- Sucking mouthparts
  Leaves empty prey
  Feeding time longer



Notes:

Seasonality and phenology

- Overwinter as adults – flight in early spring
  Most ladybirds & true bugs, some hoverflies & parasitoids, *Chrysoperla plorabunda*

- Overwinter as mature juveniles – flight in summer
  Most lacewings & spiders, some hoverflies & parasitoids

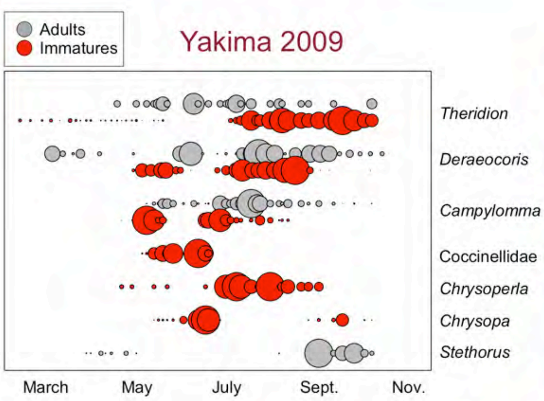
- Overwinter as eggs/young larvae – flight in summer
  Some true bugs & parasitoids

Seasonality and phenology

- Single generation each year
  Spiders, some ladybirds & ground beetles
  Slow recovery after disruption
- Multiple generations each year
  Lacewings, hoverflies, true bugs, parasitoids
  Within-season recovery after disruption

Notes:

Seasonality and phenology



Notes:

Summary

- Orchards support a high diversity of natural enemies that target different groups of arthropod pests as hosts or prey
- Two key groups of natural enemies are predators and parasitoids, and individual species vary from being highly specific on a few pest taxa to being highly generalized on numerous pest taxa

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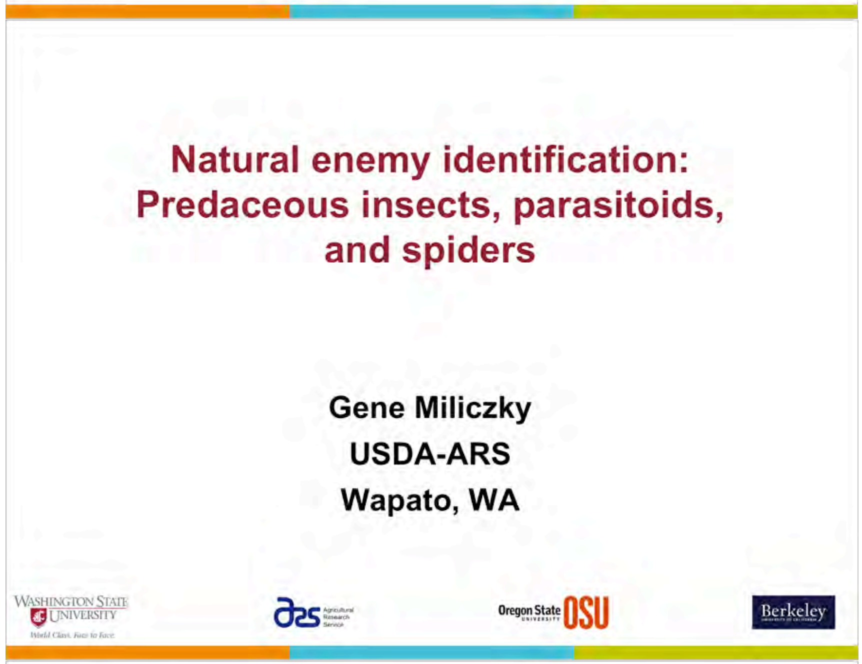
Notes:

Notes:

Presentation 4: Exercise - Natural Enemy ID

Notes:



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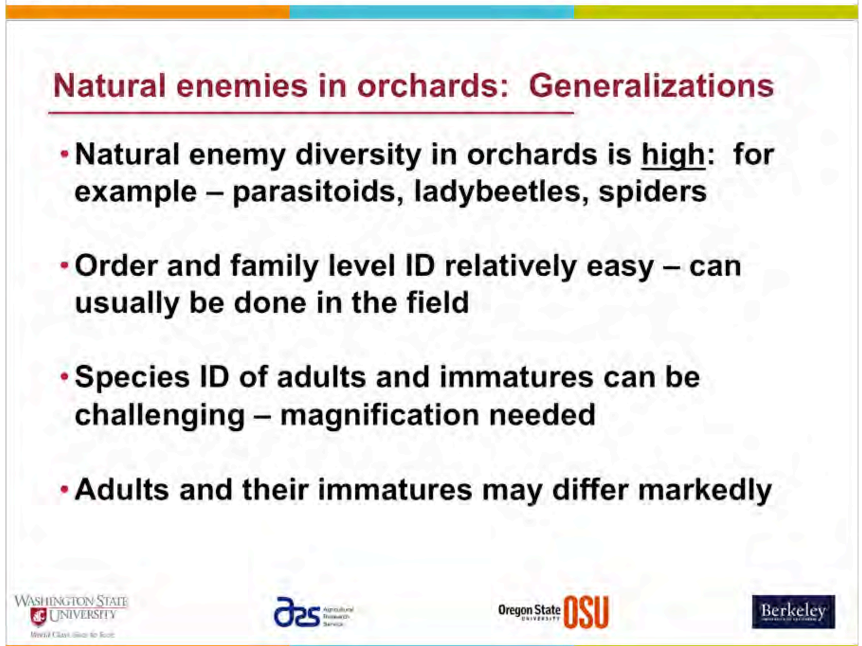


Predatory true bugs: Order Hemiptera

- Piercing-sucking mouthparts / external digestion
- Front wings have a distinctive structure
- Adults and nymphs "similar" in appearance
- Order also contains many important pests

Notes:

Deraeocoris brevis: Hemiptera, Miridae

- Adult: shiny black; 3/16"
- Nymph: mottled white, grey, pink; rather spiny
- 5 nymphal stages: tiny to nearly as large as adult
- Prey: psylla, aphids, mites
- Similar size & shape to Lygus but black color distinctive


Notes:

Campylomma: Hemiptera, Miridae

- Adult: gray-brown to yellowish tan; ~ 1/10" long
- Nymph: pale green
- 5 nymphal stages: tiny to nearly adult size
- Prey: aphids, mites, psylla
- This species also has pest status in apples

Notes:

Notes:

Orius (pirate bug): Hemiptera, Anthocoridae

- Size of adult is < 1/10”; nymphs even smaller
- Oval (adult) or pear shaped (nymph); rather flattened
- Adult is black & white; nymph usually orangish
- Prey: thrips, mites, aphids, & other small items

Notes:

Anthocoris spp. – also a pirate bug

- Adults and nymphs similar in shape & color to Orius
- Adult size: ~0.1” – 0.2”; nymphs (5 stages): tiny to near adult size
- Common in pear orchards, less common in apple
- Prey: psylla, aphids, thrips, etc.

Notes:

Lacewings: Order Neuroptera

- Two types of interest: Green and Brown
- Adults and larvae very different in appearance
- Adults have chewing mouthparts
- Larvae have piercing mouthparts

Green lacewings: Chrysopidae

Delicate, green, weak-flying adult

Stalked eggs laid singly or in groups

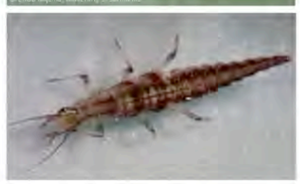
"Alligator-like" larva with large, pointed mouthparts

Cocoon contains larva or pupa

Notes:

Brown lacewings: Hemerobiidae

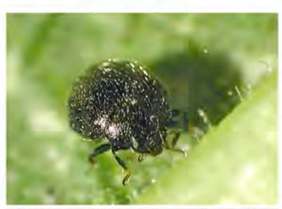
- Adults: delicate brown insects; rather weak flyers
- Larvae: elongate body; large, pointed mouthparts
- Eggs laid singly and are not stalked
- Prey: aphids, psylla, thrips



Notes:

Order Coleoptera: Beetles

- Largest insect order
- Front wings hard or leathery; not used for flight
- Adults and larvae: chewing mouthparts
- Larvae differ markedly in appearance from adults



Notes:

Notes:

Ladybird Beetles: Family Coccinellidae

- Many species are brightly colored
- Color pattern: varies little in some species but is highly variable in others
- Hemispherical or oval in shape
- Many are general predators of soft-bodied prey
- Some specialize on mites, scale, mealybugs
- Many species occur in PNW orchards (18+)

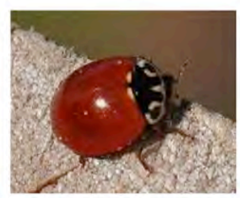
Notes:

Some common LB's in PNW orchards


Convergent


7-spot

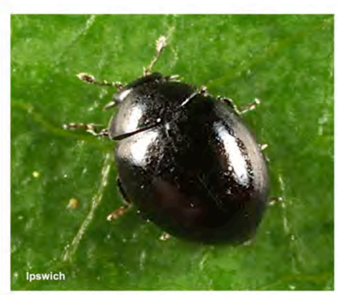

Halloween


Polished

Notes:

Two specialist LB's in PNW orchards

Stethorus
mite predator



Microweisea
scale predator

Immature stages of Ladybird Beetles

Eggs spindle-shaped;
often yellowish;
laid in groups

Larva elongate with
spines & tubercles;
often has colorful markings

Notes:

Ground beetles: Family Carabidae

- Very large family of beetles
- Elongate, somewhat flattened
- Ground dwellers; rare in trees
- Adults and larvae predaceous; some may feed on codling moth
- Most are active at night
- Some species quite large: ½”+

Pterostichus – common on ground in orchards

Notes:

Order Diptera: true flies

- Front wings well developed for flight
- Hind wings much reduced; not used for flight
- Adults and larvae (maggots) differ in appearance, food preferences, and habitat

Notes:

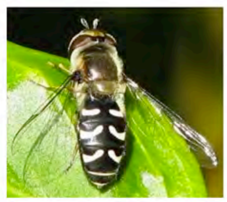
Notes:

Family Syrphidae: flower- or hoverflies

- Species of interest are aphid predators in the larval stage
- Larvae are typical maggots in appearance
- Adults of many species bear general resemblance to wasps or bees
- Adults feed on nectar and pollen and are of some benefit as pollinators

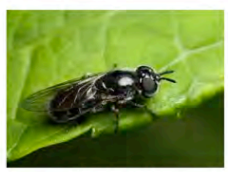
Notes:

Common syrphids in PNW orchards



Scaeva

Eupeodes



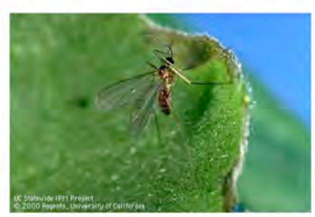
Heringia

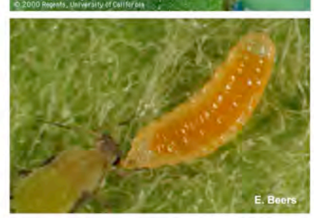
Syrphid larva

Notes:

Cecidomyiidae: *Aphidoletes aphidimyza*

- Adult is a tiny, delicate fly; smaller than a mosquito
- Predaceous larva is orange and ~ 1/8" long
- Prey: aphids, thrips, mites, and other small insects





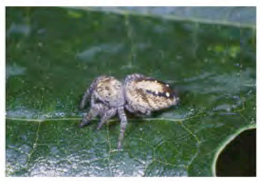
Spiders: Arachnida, Araneae

- Spiders have 8 legs and (usually) 8 eyes
- Spiders have 2 body regions
- All spiders are predaceous
- All spiders spin silk for webs, egg sacs, etc.
- Spider webs are highly variable in form but
- Many spp active hunters and do not spin webs
- Abundant/diverse in low insecticide orchards

Notes:

Common spiders in PNW orchards (1)

Jumper - *Phidippus*



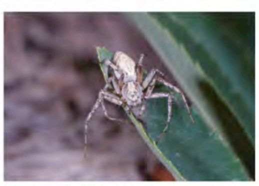
Jumper - *Pelegrina*

Crab - *Xysticus*

Crab - *Misumenops*

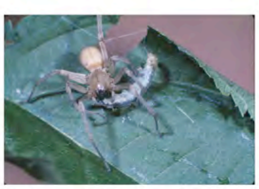
Notes:

Common spiders in PNW orchards (2)

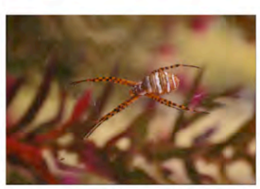


Lynx spider - *Oxyopes*

Philodromus cespitum



Sac spider w / PLR



Orb-weaver in her web

Notes:

Notes:

Predatory mites: Arachnida, Acari

- Mites are relatives of spiders: have 8 legs and 2 body regions
- Most are tiny, barely visible to naked eye
- Predatory mites are the most important biocontrol agents of phytophagous mites
- Biocontrol of mites has several benefits

Notes:

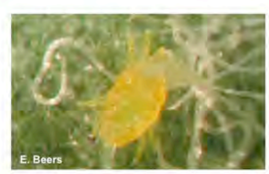
Typhlodromus occidentalis: western predatory mite

- Native to western U.S.
- Eggs are oval in shape
- Larval stage has only 6 legs
- Adult ~ 1/3 mm long and rather pear shaped
- Takes on color of recently consumed prey
- Prey: spider and rust mites

Notes:

Zetzellia mali: predatory mite

- Native to the U.S.
- Eggs are round and yellow
- Adults and immatures yellow but take on color of prey
- Oval in shape
- Prey: spider mites but will also take other predator mites



Insect parasitoids: general considerations

- Two important orders: Diptera & Hymenoptera
- Diptera represented by family Tachinidae
- Hymenoptera: 20+ families on trays and cards
- However, importance in orchard biocontrol, if any, of many of them is unknown
- Many of the Hymenoptera are very small and difficult to ID

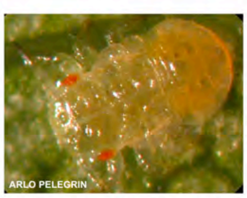
Notes:

Trechnites psyllae: pear psylla parasitoid

- Important pear psylla parasitoid in PNW
- Tiny wasp (~1/25”) in family Encyrtidae
- Dark body, pale legs, metallic blue patch on dorsal surface
- Overwinters inside the host
- 1st gen. adults search flowers & buds for hosts
- Adults often stay on beat tray for some time

Notes:

Trechnites psyllae: pear psylla parasitoid



Pear psylla nymph

Trechnites adult

Parasitized nymph (mummy)

Notes:

Notes:

Aphelinus mali: wooly apple aphid parasitoid

- Primary importance is as a WAA parasitoid
- Tiny wasp (~1/25") in family Aphelinidae
- Black, non-metallic body w / pale band at base of abdomen
- Can be abundant in low insecticide orchards where the host is present
- Can be spotted on beat tray; may not fly immediately

Notes:

Aphelinus mali and its host

Aphelinus mali adult


WAA mummy showing *A. mali* emergence hole

Notes:

Colpoclypeus florus: leafroller parasitoid

- Wasp is native to Europe; established in PNW
- Adult is a tiny wasp (family Eulophidae)
- Several / many eggs laid per host
- Wasp larvae feed externally
- Hosts: PLR, OBLR, strawberry LR, et al.
- Best evidence for presence: Parasitized LR's
- Overwintering host is needed

Colpoclypeus florus: leafroller parasitoid

C. florus attacking OBLR

Feeding *C. florus* larvae

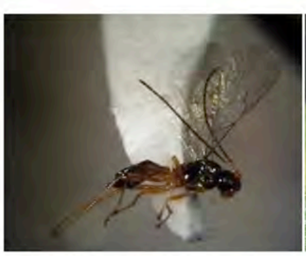
Notes:

Aphidiinae: aphid parasitoids

- Subfamily in the large family Braconidae
- All species are internal parasitoids of aphids
- Tiny, slender, brown or black wasps
- Parasitized aphids – “mummified” appearance
- Common rosy apple aphid parasitoids
- *Trioxys* sp. parasitizes walnut aphid in CA

Notes:

Aphidiinae: aphid parasitoids



Aphidiinae: *Trioxys* sp.

Aphid “mummy”

Notes:

Notes:

Tachinidae: parasitic flies

- Most important family of parasitoid flies
- Large group with 1000's of species
- Size varies greatly; have the "housefly" look
- Some have a marked "bristly" appearance
- Rarely show up on beat trays as they fly away
- Several species have been reared from our pest leafrollers

Notes:

Tachinidae: parasitic flies

Typical tachinid

Tachinid maggot and host

NE Monitoring – Jones, Mills, Horton, Unruh, Shearer

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Notes:

Overview

- Why monitor at all
  - Pests
  - Natural enemies
- Improving NE monitoring
  - "Messages" from monitoring
- SCRI accomplishments
  - Development of HIPV traps
  - Using traps to monitor management
- Summary

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Notes:

HIPV Abbreviations

- AA – acetic acid
- AP – acetophenone
- GER - geraniol
- PAA – phenylacetaldehyde
- MS – methyl salicylate
- PE – 2 Phenyl ethanol
- GMP – GER + MS + PE
- SQ – squalene

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Notes:

Notes:

Why monitor pests?

- Improved timing of treatments
- Spray only when & where needed
- Link severity of tactics to pest severity
- Decreased:
  - Management costs
  - Resistance potential
  - Export issues (MRL violations)
  - Secondary pest issues
- Improved
  - Worker safety
  - Environmental quality
  - Consumer acceptance

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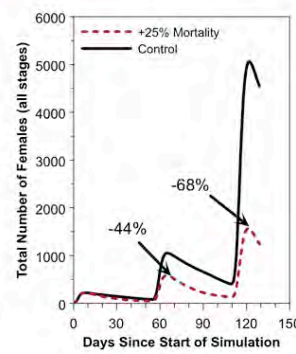
Notes:

Why monitor NE?

- NE provide pest suppression
  - Eliminate NE
    - Need to pay for mortality they provide
    - May affect multiple secondary pests
    - A small amount of mortality = big impact
- Timing of IPM tactics affects NE
  - Goal is to minimize impacts on NE
- Abundance and phenology of NE should guide tactics used



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Notes:

What you don't know can hurt you…

- Current NE sampling is inefficient
- Leads to false impressions
  - Nothing caught = BC unimportant
- Beating Trays
  - Samples insects only from the plant disturbed by the beat
  - Affected by daily activity patterns
  - Particularly poor for good fliers

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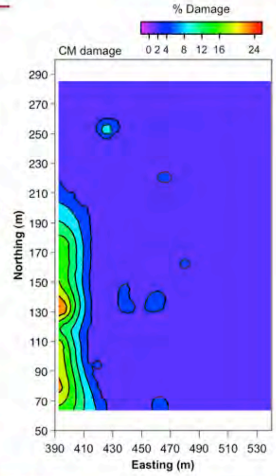
Can we improve NE monitoring?

- Herbivore-Induced Plant Volatiles (HIPVs)
  - Insect feeding = changed volatile bouquet
  - NE home in on certain volatiles
    - Restricts their search
    - Improves their ability to find pest at low density
    - Improved pest regulation
- HIPVs can often be bought off the shelf
  - Gives us ability to monitor NE



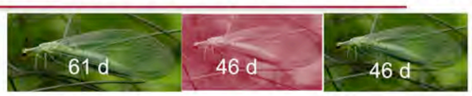
Notes:

HIPV traps: *We have the technology..*

- Accumulate captures over time
  - Not sensitive to daily activity patterns
- Draw from entire active space
  - Within tree or between trees
- Very specific or very broad taxonomic response
  - Depends on lure/trap combination
- Primarily good for adult stages

Notes:

Monitoring dictates perception and management

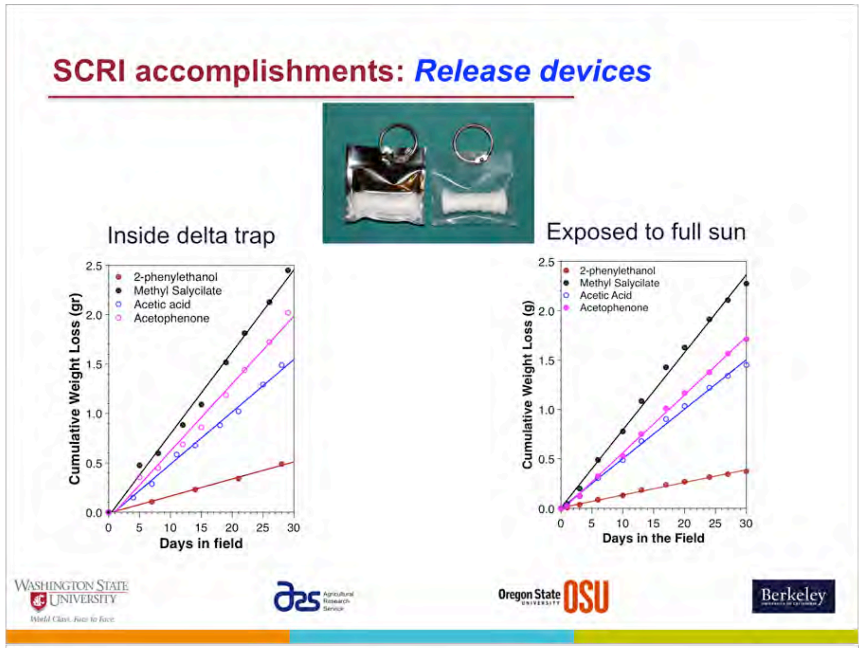


46 vs 153 days

Same 5 Orchards Sampled	Beating Tray	Attractant Traps
Sampling Frequency	2-3 times/wk	1 time per week
Sample Period	March-October	March-October
No. Samples per orchard	50 trees	4 traps
No. Caught	12	25,604
Message	Rare in space and time	Abundant throughout the season
Importance to BC & Management	None	Protect and use this NE!

Notes:

Notes:



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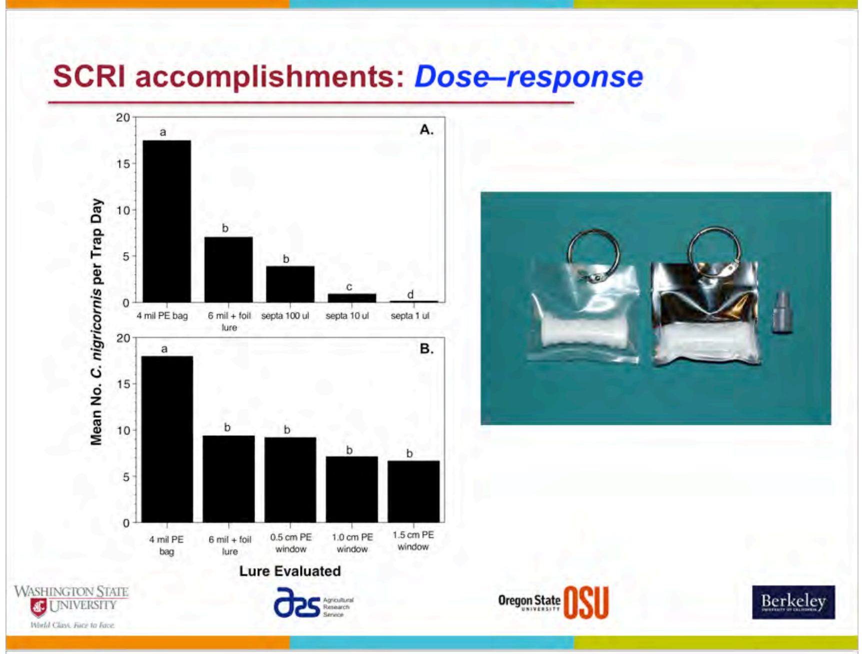

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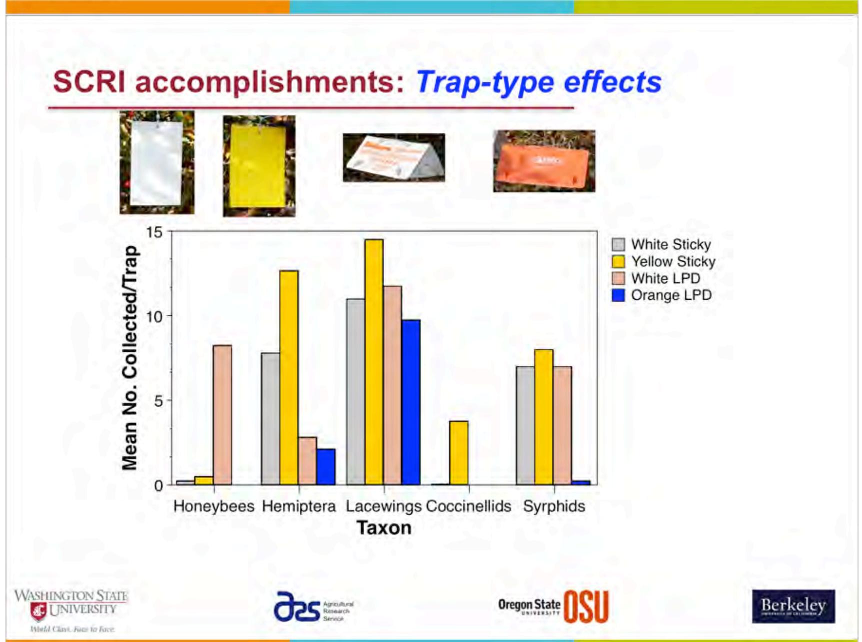

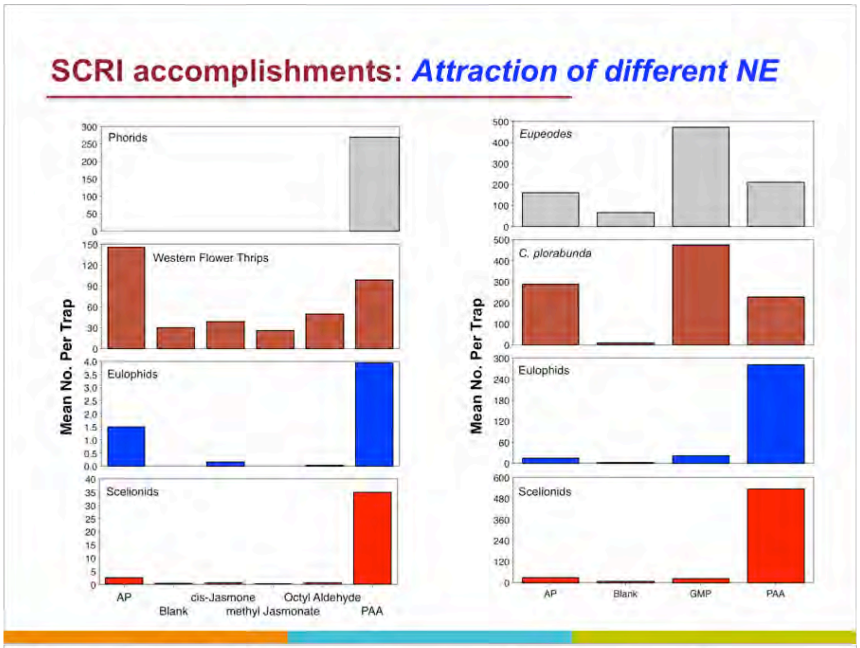

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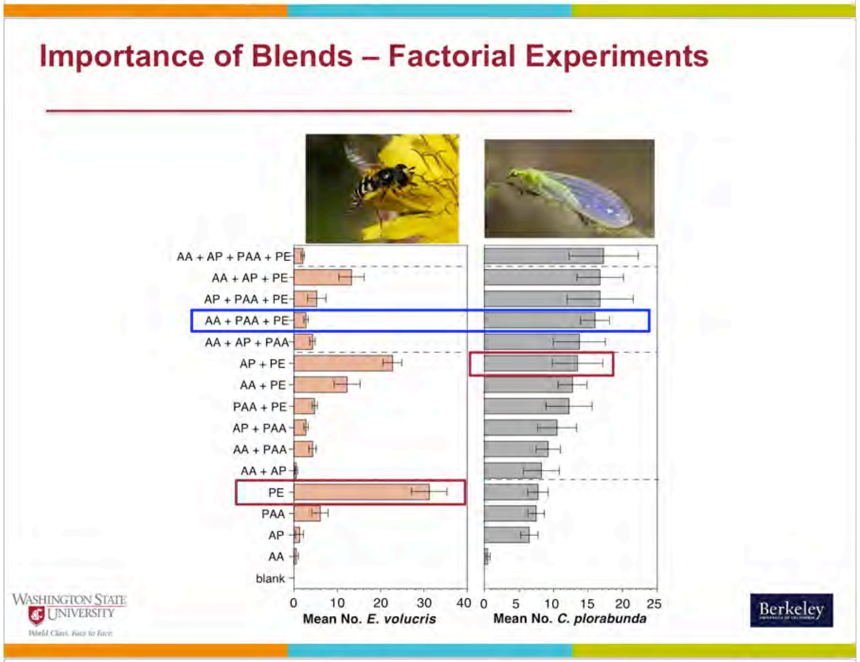

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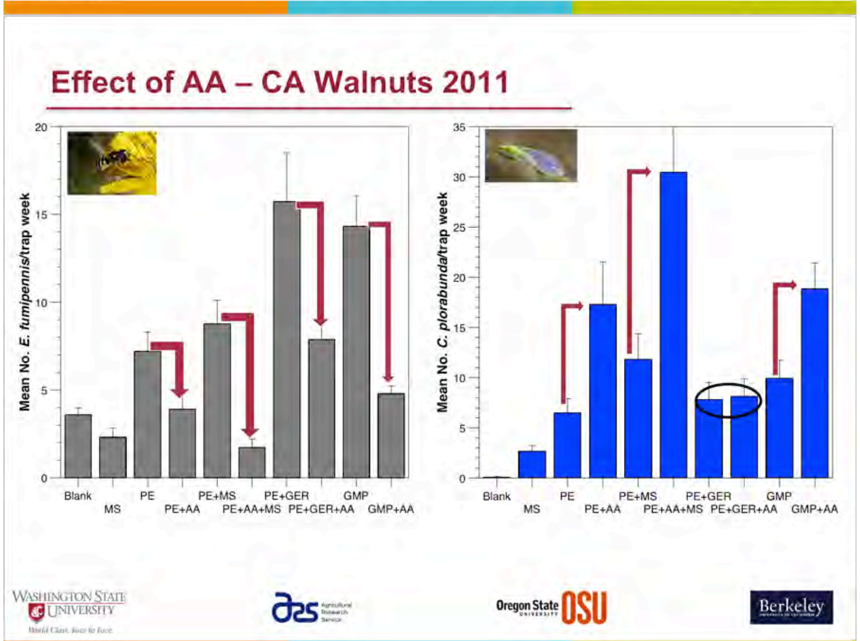
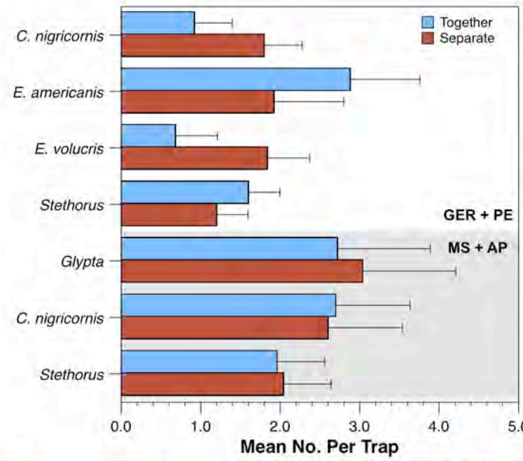


Notes:

Notes:

Mixing attractants – simpler lures



Notes:

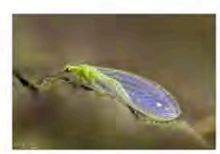
Attractants–Targets

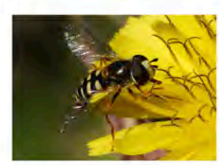
- Similar responses between crops
- Variability in response to attractants, even within closely related groups
- Specific
  - Squalene - only male *C. nigricornis*
- General
  - GMP
    - Lacewings
    - Syrphid flies
    - Broad diversity of parasitoids

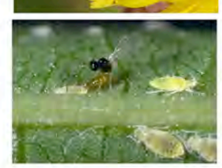
Notes:

Using general attractants

- Problem of information overload
- Focus on 1-few indicator species
  - Lacewings
  - Syrphids
  - Specific parasitoids
- Indicator species then can be used
  - Comparison of management tactics
  - Before-after pesticide treatments







Value of traps

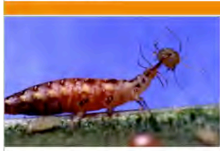
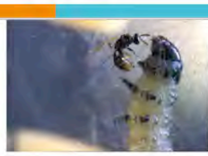
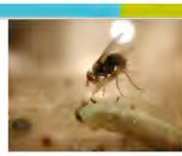
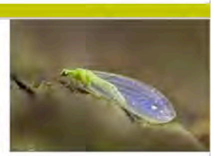
- You can readily see the “indicator” NE species
  - Brings the value of BC home!
- Evaluate how management effects NE complex
- Choose severity of tactics based on NE abundance
  - Act to correct imbalances in pest/NE

Notes:

Summary

- Monitoring is critical for stable IPM programs
- Good NE monitoring tools been developed
  - Looking for commercialization of lures
- Focus on several “indicator species”
  - Use to compare management programs
  - Before-After comparison for management tactics
- NE provide an important service
  - Stability of secondary pest populations
  - Eliminate NE, you must pay to replace their services
- HIPVs for NE monitoring ≈ pest pheromones for IPM

Notes:

Natural Enemy Phenology, Modeling, and IPM

Vince Jones

Department of Entomology, WSU-Tree Fruit Research and Extension Center, Wenatchee, WA

Presentation 6: NE Phenology, Modeling and IPM

Notes:

Notes:

Overview

- Why model NE?
- Differences in predator and parasitoid models
- Basis of models and how they are developed
  - Laboratory studies
  - Field studies
- Windows of opportunity
- SCRI grant contributions
- Getting the information to the pest manager

Notes:

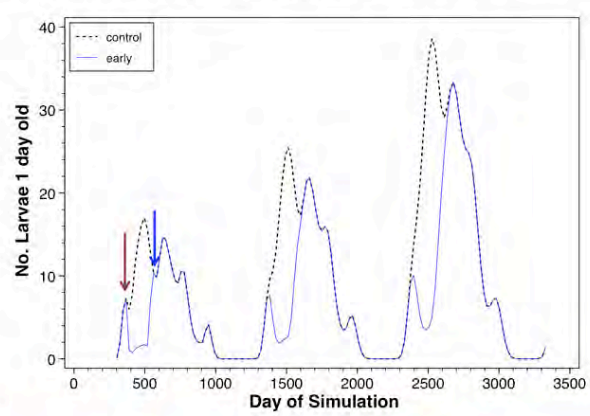
Why model NE?

- NE reduce pest pressure & stabilize system
  - Eliminate NE, expect to pay for it!
- Minimize exposure of NE to pesticides
  - In Space
  - In Time
- Only certain stages are exposed to pesticides
  - "Windows of Opportunity"
- Sensitive times in NE life history
  - "Windows of Trouble"
- New models provide more than just phenology

Notes:

Why are management programs unstable?

- Pesticides are applied at specific time for pest
- NE phenology unknown – effects are random



Why are management programs unstable?

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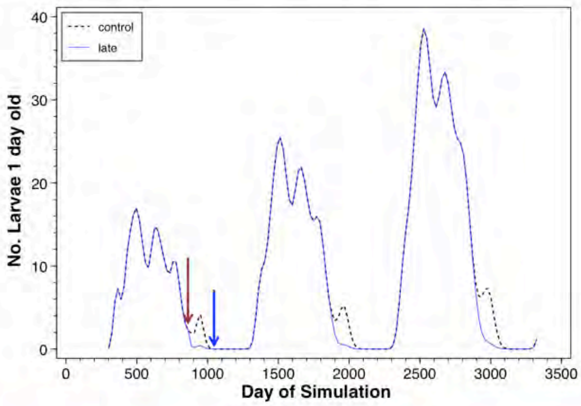
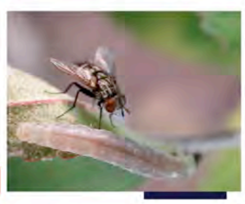


Notes:

Predator vs parasitoid models

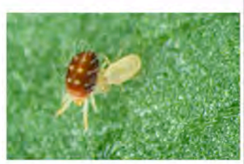
- Parasitoids
  - Rigidly associated with a particular host stage
  - Some are very specific
    - Only certain ages/sizes attacked
    - Only certain pests attacked
  - Some are generalists
- May be able use the pest model
  - Avoid sprays when parasitoids are present
  - Windows of opportunity!

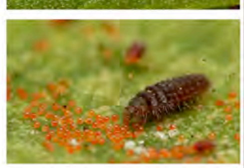


Notes:

Predator Models

- Free-living
- Often only loosely associated with prey
- May attack multiple pests
  - May switch depending on abundance
- Models are more difficult to develop
  - Harder to sample
  - Prey presence/absence may distort phenology
  - May have extensive overlap in generations





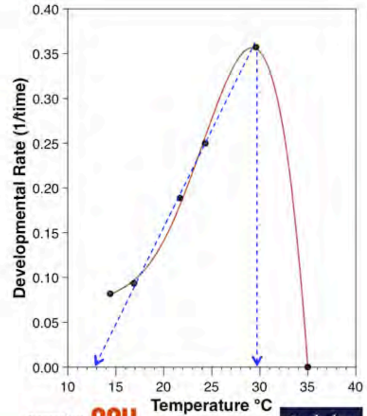
Notes:

Notes:

Laboratory Studies

How models work

- Insect temperature ≈ air temperature
- Development driven by heat
  - Amount needed is constant
  - Accumulation rate not important
- Thresholds
  - Lower
  - Upper
- Heat Units are Degree-Days



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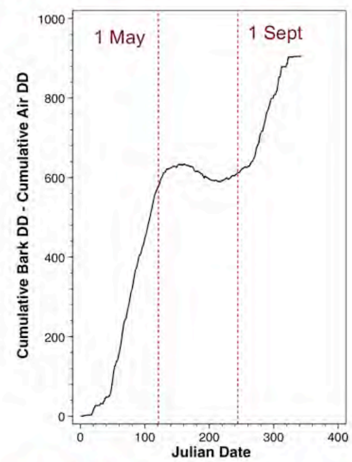
Notes:

Field Studies

Importance of Environmental Data

- Environmental data must reflect where insects are developing
  - Station placement
  - Solar radiation
- Orchard architecture/management
  - Tree density
  - Overhead cooling



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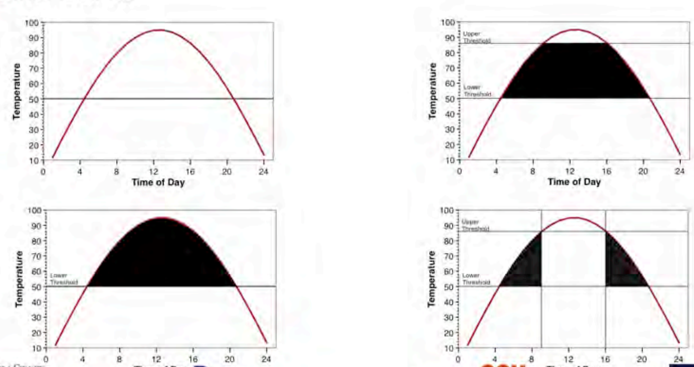
Notes:

Field Studies

Calculating Heat Units (Degree-Days)

- Ancient Method
  - $DD = \frac{(\max + \min)}{2}$
- Sine Curve



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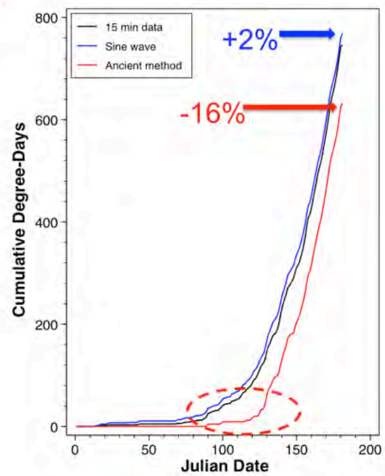
Accuracy of Methods

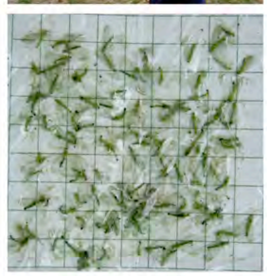
- If 15 min data are the standard:
  - Sine wave over slightly
  - Ancient method grossly low
    - Particularly problem in spring
- Sine wave is broadly used
  - Data are easier to obtain
  - Accuracy loss is minimal
  - Most insect models have used this since late 1960's



Notes:

Field Validation

- Need multiple years, multiple sites
  - Variability in conditions and weather patterns
  - Need pests for NE presence
- Reliable sampling method
- Unsprayed or "lightly" treated orchards
- Pesticides change apparent phenology



Notes:

SCRI Project Work

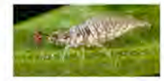
- Monitoring NE in apple, pear, walnut, sweet cherry
  - Multiple years, multiple sites/crop
- Temperature data in each location
- Some data sets are more restricted
  - Walnut aphid parasitoid
  - Woolly apple aphid parasitoid
- Most models have not been started
  - Expect models for lacewings, syrphid flies
  - Walnut aphid parasitoid
  - Woolly apple aphid parasitoid

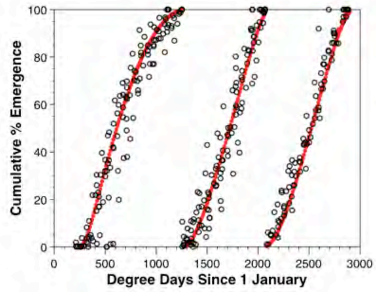
Notes:

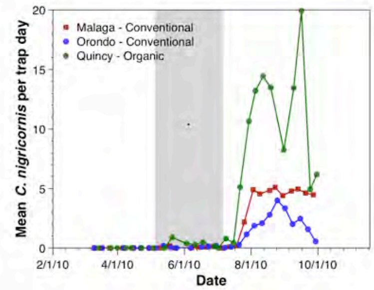
Notes:

SCRI Contributions

Predator Models – *C. nigricornis*







apple, walnut, sweet cherry

sweet cherry is missing gen 1

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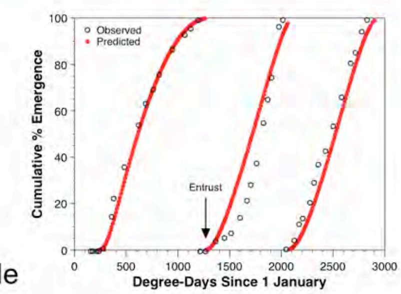
Notes:

SCRI Contributions

Distortion of phenology in field

- Distortion may be subtle
- Estimator of pesticide effects
- Multiple factors important
  - Amount of mortality
  - Duration of mortality
  - When mortality occurs
- Working on quantifying pesticide effects



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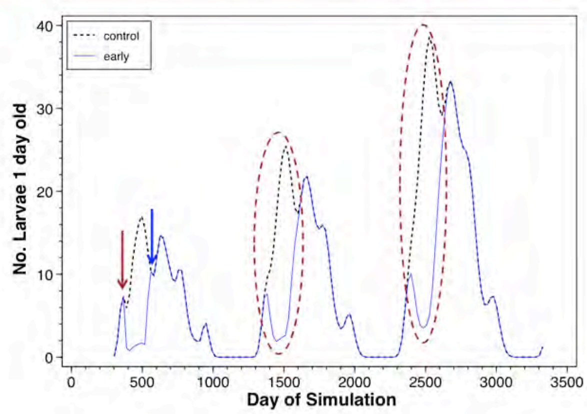
Notes:

SCRI Contributions

Timing effects and persistence of effects



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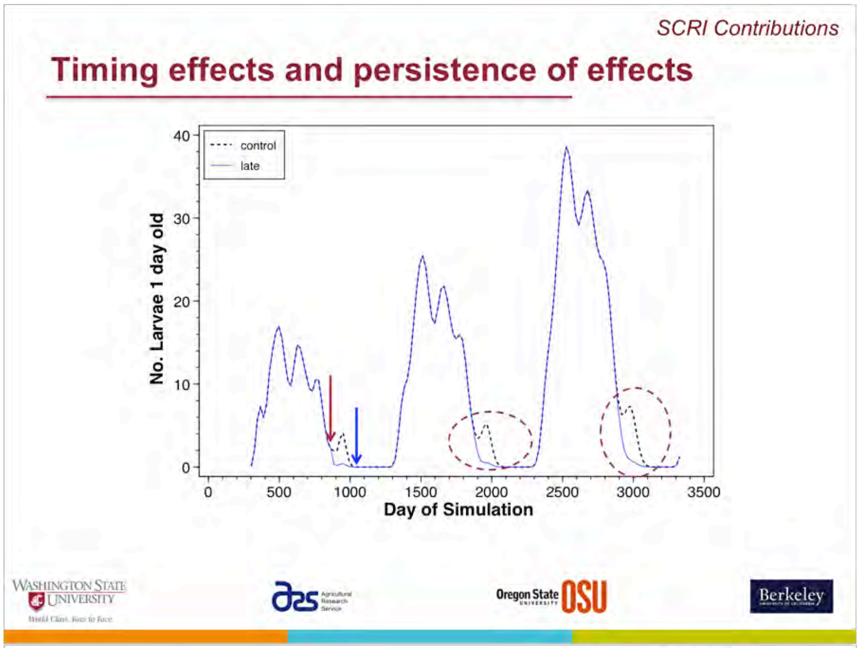

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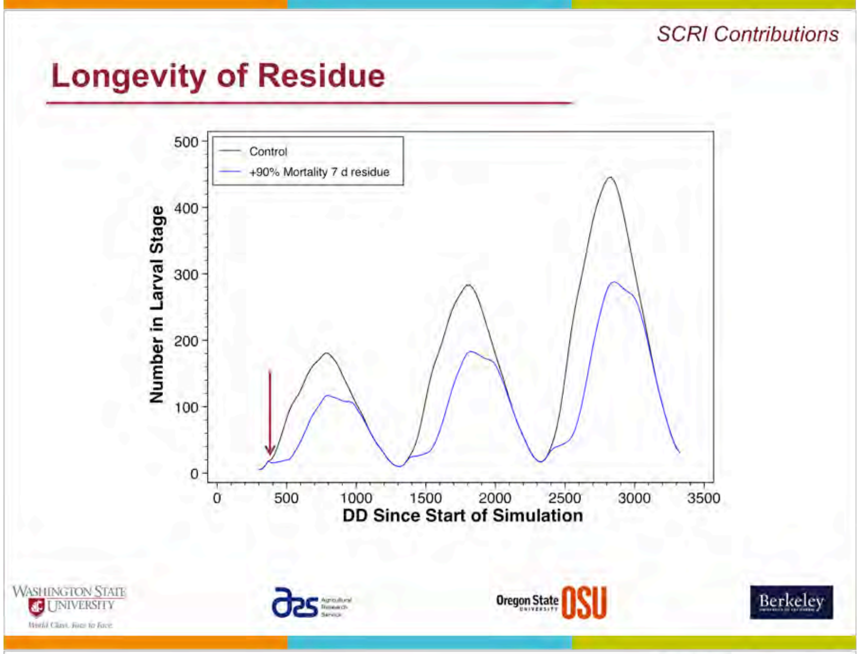

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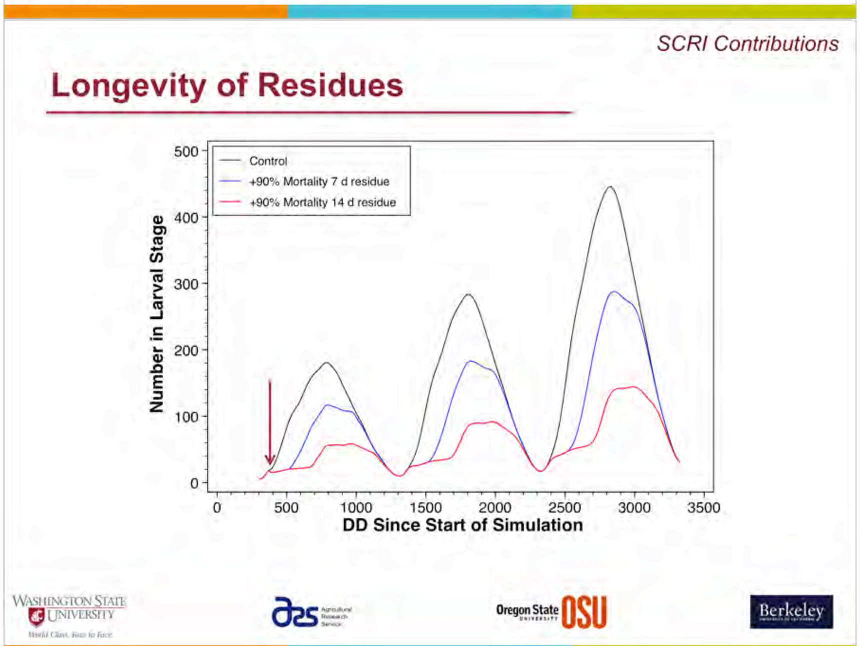

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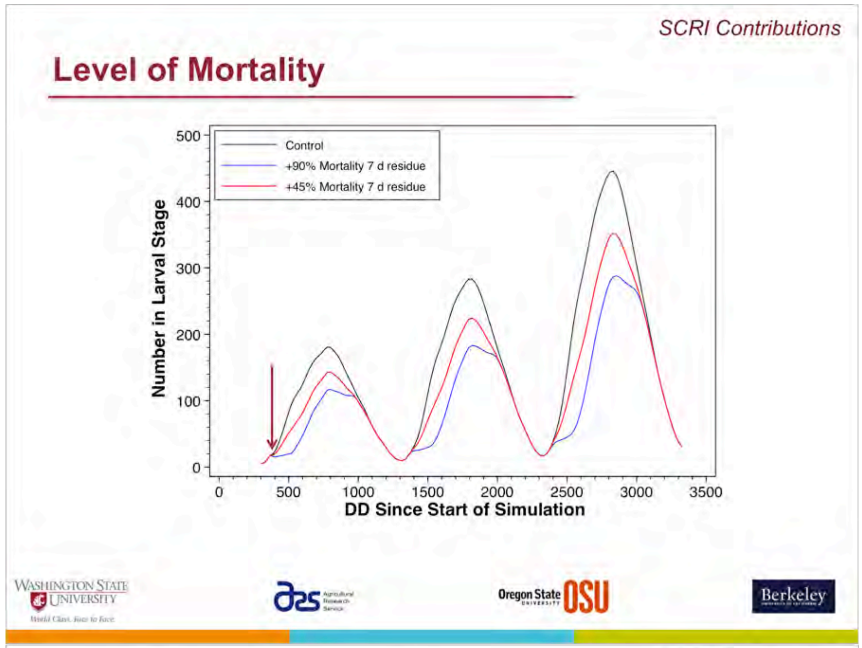

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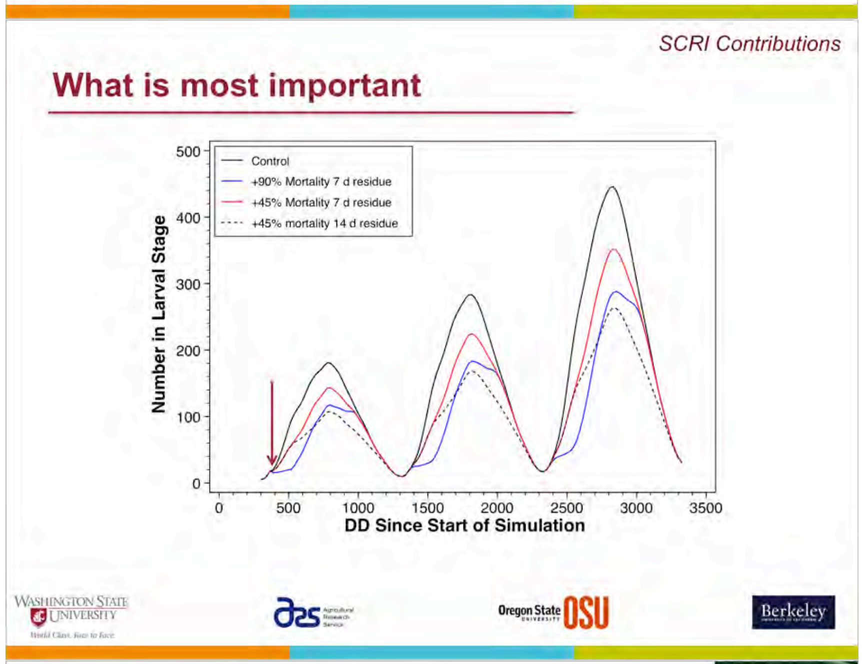

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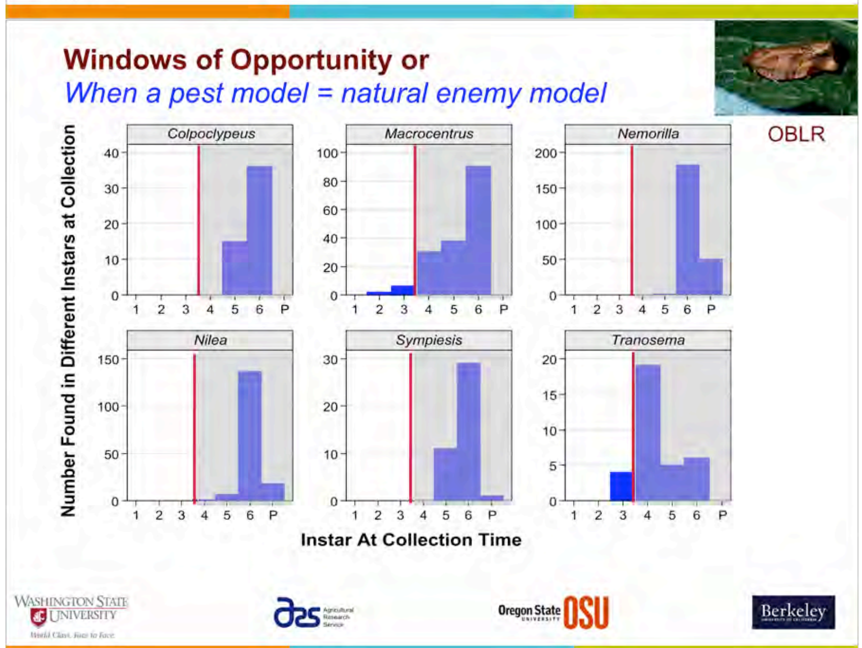
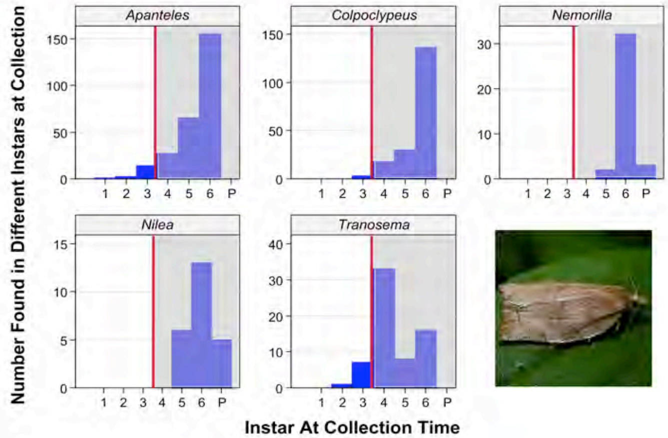


Windows of Opportunity



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Notes:

And the experts say…..

- Q1: You've used models for pests, do you think the same ideas will work for NE?
- Q2: Do you use the leafroller models on DAS and the recommendations to preserve NE?
- Q3: Would you be interested in NE phenology and how it could help your IPM program?
- Q4: How would you like information about NE phenology presented?

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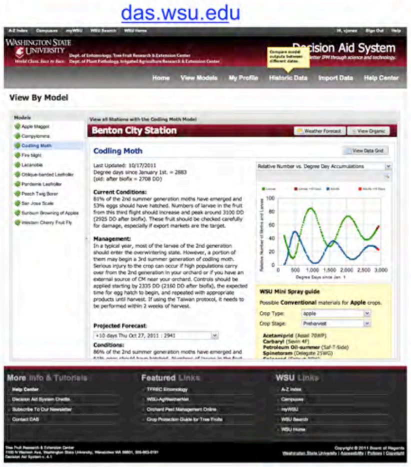
Notes:

Getting the information to pest manager

das.wsu.edu



enhancedbiocontrol.org

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Notes:

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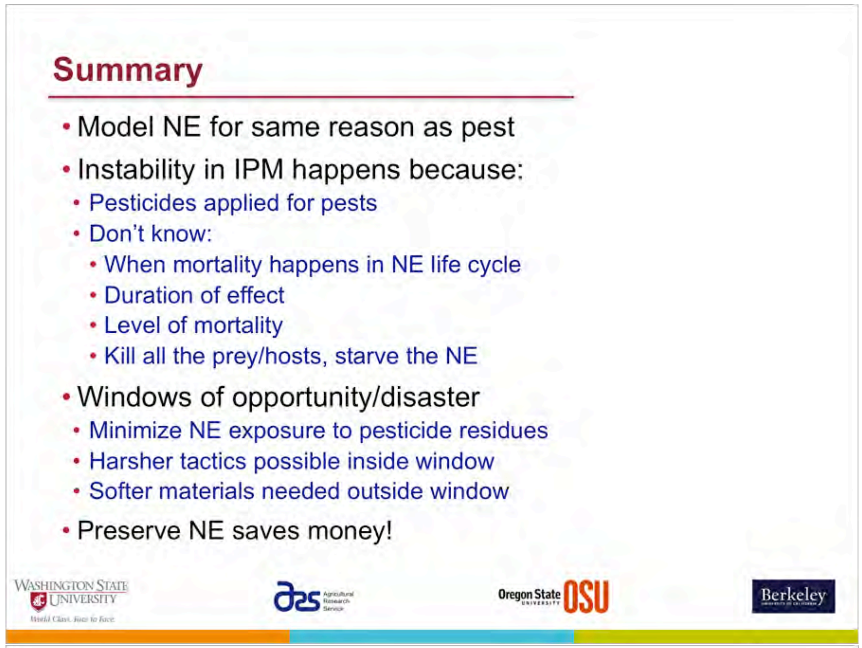
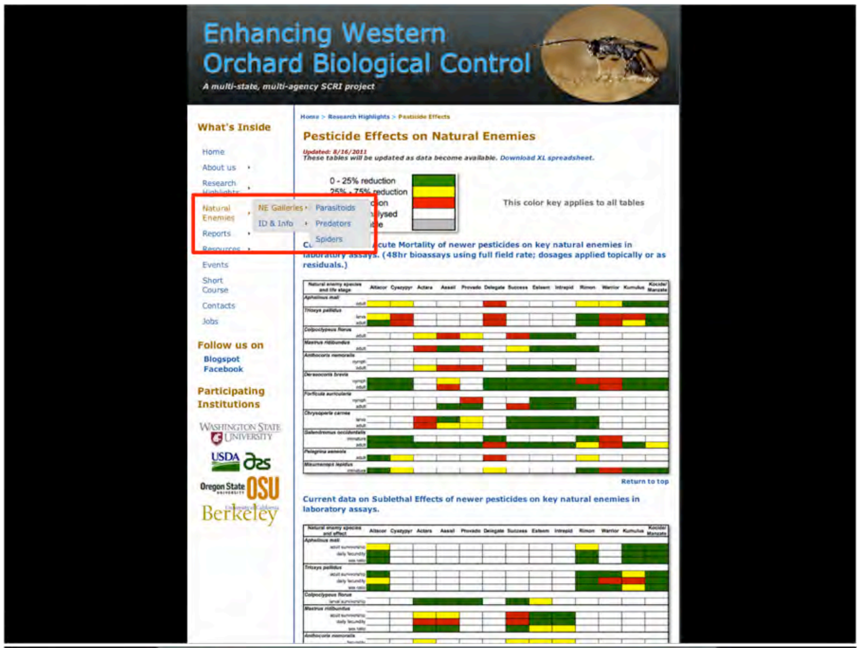


Presentation 7: BC Resources on the Web

Notes:

(A full list of web resources is on page 197 in this workbook.)

Notes:



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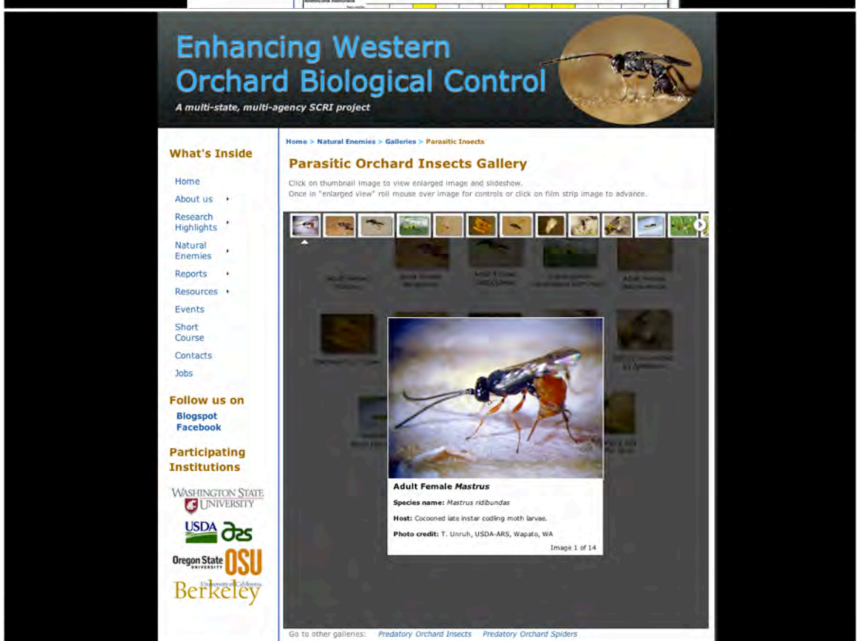

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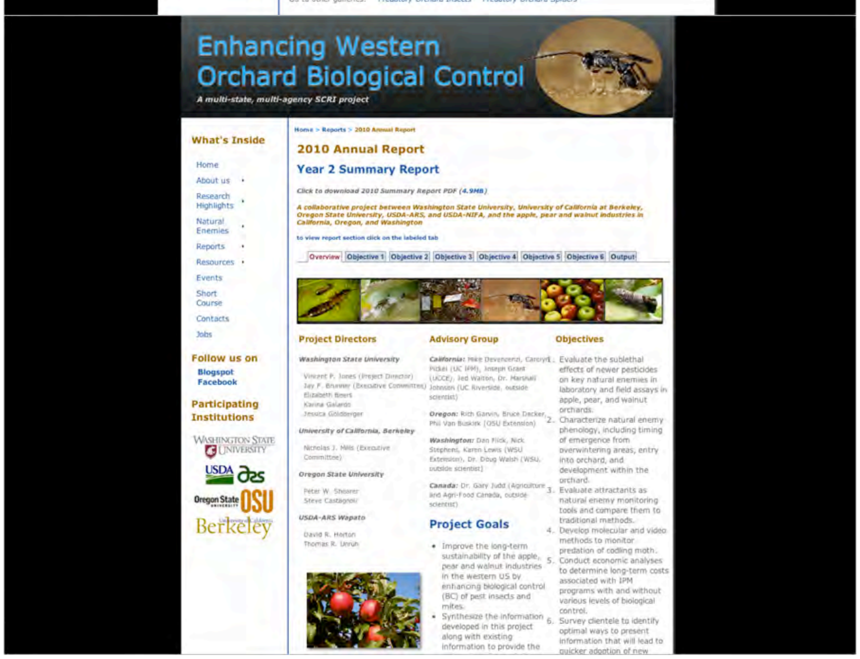

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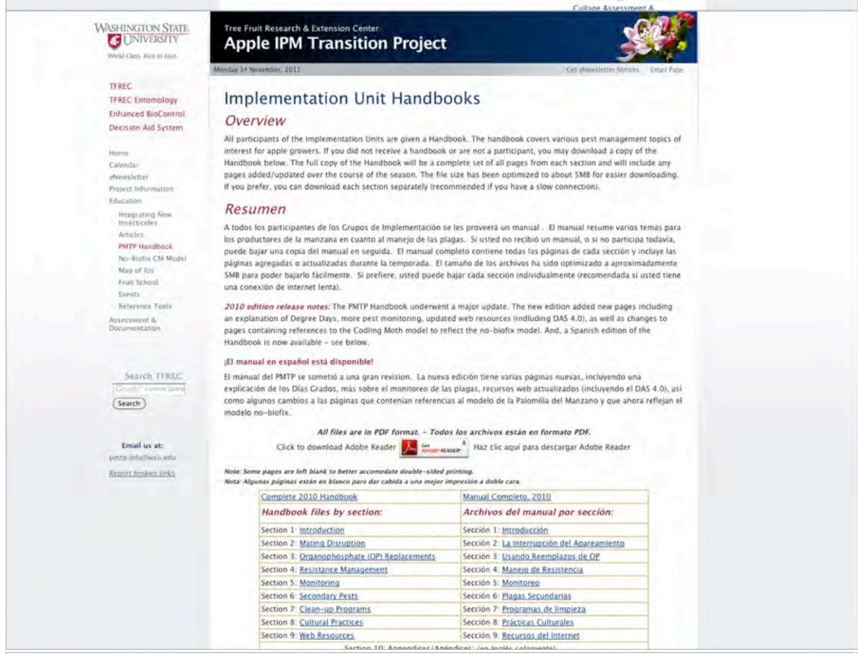

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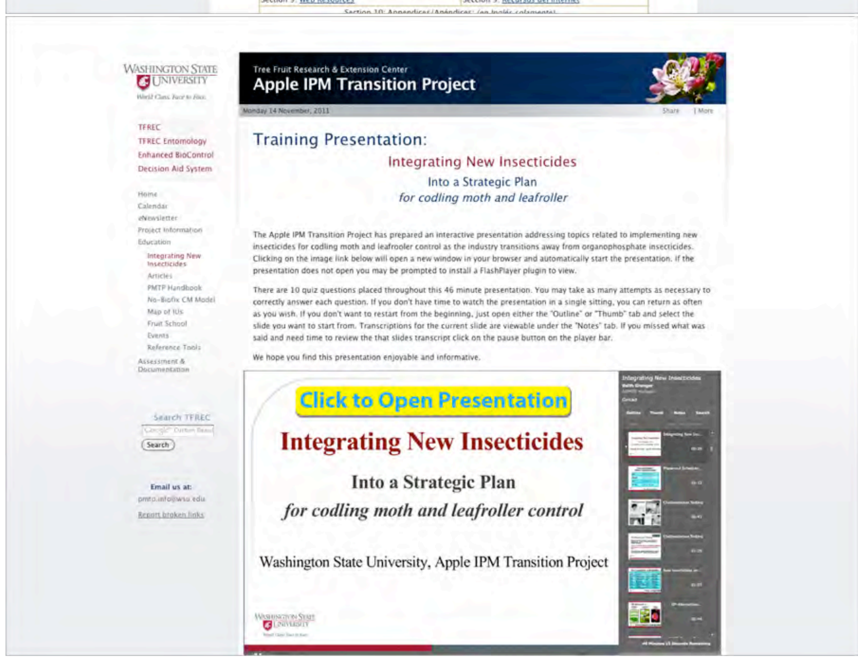
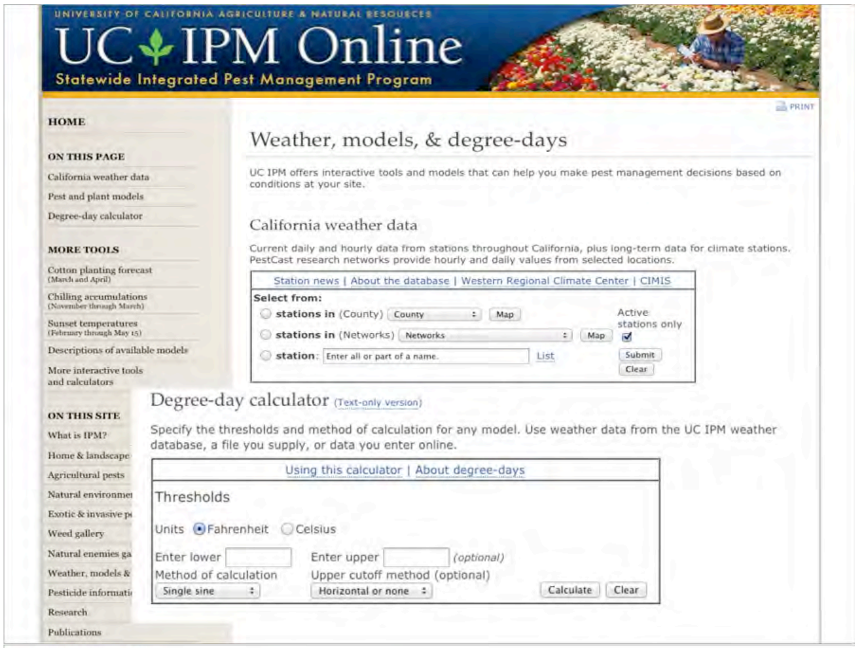




UNIVERSITY OF CALIFORNIA AGRICULTURE & NATURAL RESOURCES
UC IPM Online
Statewide Integrated Pest Management Program

PRINT

HOME

ON THIS PAGE
- California weather data
- Pest and plant models
- Degree-day calculator

MORE TOOLS
- Cotton planting forecast (March and April)
- Chilling accumulations (November through March)
- Sunset temperatures (February through May 15)
- Descriptions of available models
- More interactive tools and calculators

ON THIS SITE
- What is IPM?
- Home & landscape
- Agricultural pests
- Natural environme
- Exotic & invasive p
- Weed gallery
- Natural enemies ga
- Weather, models &
- Pesticide informati
- Research
- Publications

Weather, models, & degree-days

UC IPM offers interactive tools and models that can help you make pest management decisions based on conditions at your site.

California weather data

Current daily and hourly data from stations throughout California, plus long-term data for climate stations. PestCast research networks provide hourly and daily values from selected locations.

Station news | About the database | Western Regional Climate Center | CIMIS

Select from:
- **stations in** (County) County — Map
- **stations in** (Networks) Networks — Map
- **station:** Enter all or part of a name. — List

Active stations only — Submit — Clear

Degree-day calculator (Text-only version)

Specify the thresholds and method of calculation for any model. Use weather data from the UC IPM weather database, a file you supply, or data you enter online.

Using this calculator | About degree-days

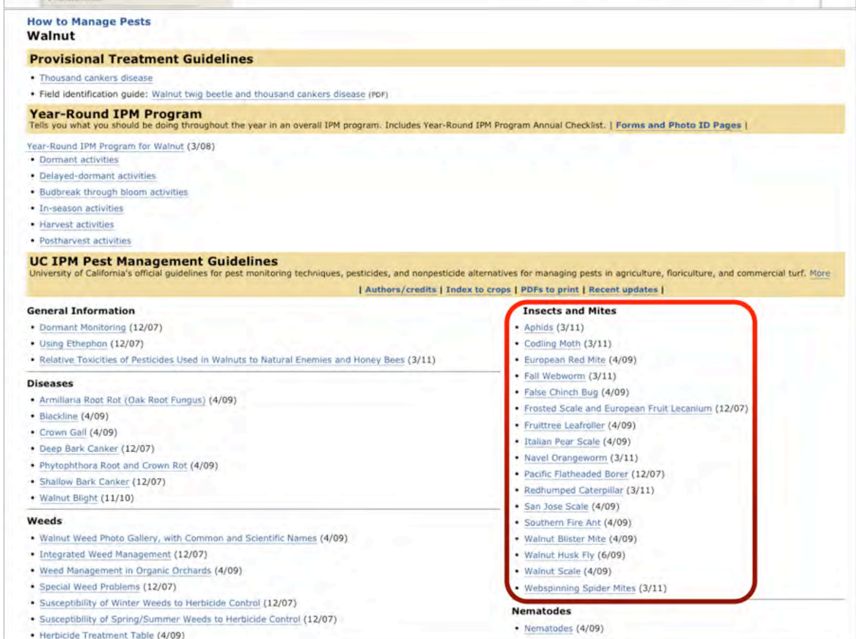
Thresholds

Units: Fahrenheit / Celsius

Enter lower — Enter upper (optional)

Method of calculation: Single sine — Upper cutoff method (optional): Horizontal or none — Calculate — Clear

Notes:



How to Manage Pests
Walnut

Provisional Treatment Guidelines
- Thousand cankers disease
- Field identification guide: Walnut twig beetle and thousand cankers disease (PDF)

Year-Round IPM Program
Tells you what you should be doing throughout the year in an overall IPM program. Includes Year-Round IPM Program Annual Checklist. | Forms and Photo ID Pages |

Year-Round IPM Program for Walnut (3/08)
- Dormant activities
- Delayed-dormant activities
- Budbreak through bloom activities
- In-season activities
- Harvest activities
- Postharvest activities

UC IPM Pest Management Guidelines
University of California's official guidelines for pest monitoring techniques, pesticides, and nonpesticide alternatives for managing pests in agriculture, floriculture, and commercial turf. More
| Authors/credits | Index to crops | PDFs to print | Recent updates |

General Information
- Dormant Monitoring (12/07)
- Using Ethephon (12/07)
- Relative Toxicities of Pesticides Used in Walnuts to Natural Enemies and Honey Bees (3/11)

Diseases
- Armillaria Root Rot (Oak Root Fungus) (4/09)
- Blackline (4/09)
- Crown Gall (4/09)
- Deep Bark Canker (12/07)
- Phytophthora Root and Crown Rot (4/09)
- Shallow Bark Canker (12/07)
- Walnut Blight (11/10)

Weeds
- Walnut Weed Photo Gallery, with Common and Scientific Names (4/09)
- Integrated Weed Management (12/07)
- Weed Management in Organic Orchards (4/09)
- Special Weed Problems (12/07)
- Susceptibility of Winter Weeds to Herbicide Control (12/07)
- Susceptibility of Spring/Summer Weeds to Herbicide Control (12/07)
- Herbicide Treatment Table (4/09)

Insects and Mites
- Aphids (3/11)
- Codling Moth (3/11)
- European Red Mite (4/09)
- Fall Webworm (3/11)
- False Chinch Bug (4/09)
- Frosted Scale and European Fruit Lecanium (12/07)
- Fruittree Leafroller (4/09)
- Italian Pear Scale (4/09)
- Navel Orangeworm (3/11)
- Pacific Flatheaded Borer (12/07)
- Redhumped Caterpillar (3/11)
- San Jose Scale (4/09)
- Southern Fire Ant (4/09)
- Walnut Blister Mite (4/09)
- Walnut Husk Fly (6/09)
- Walnut Scale (4/09)
- Webspinning Spider Mites (3/11)

Nematodes
- Nematodes (4/09)

Notes:

UNIVERSITY OF
UC
Statew

Predators

A predator is an organism that attacks, kills, and feeds on several to many other individuals (its prey) in its lifetime.

Common name	Scientific name
Twicestabbed lady beetle	*Chilocorus orbus*
Vedalia beetle	*Rodolia cardinalis*
Western predatory mite	*Galendromus occidentalis*

PRINT

HOME

LIST NATU
- By order and
- By scientific
- By pest

ON THIS P
- Predators
- Insect parasi

ON THIS S
- What is IPM
- Home & lanc
- Agricultural
- Natural envi

Insect parasites (parasitoids)

Larval stages of insect parasites feed on or inside of other insects, killing their hosts. Adults are free-living wasps or flies.

Common name	Scientific name
Anaphes species	*Anaphes iole, Anaphes nitens*, and other *Anaphes* spp.
Aphidius species	*Aphidius* spp.
Aphytis spp., armored scale parasites	*Aphytis* spp.
Bracon cushmani, grape leaffolder parasite	*Bracon cushmani*
Citrus mealybug parasite	*Leptomastix dactylopii*
Cotesia medicaginis, alfalfa butterfly parasite	*Cotesia medicaginis*
Cottony cushion scale parasite	*Cryptochaetum iceryae*
Elm leaf beetle parasite	*Erynniopsis antennata*
Encarsia formosa, whitefly parasite	*Encarsia formosa*
Hyposoter exiguae, caterpillar parasite	*Hyposoter exiguae*
Lysiphlebus testaceipes, aphid parasite	*Lysiphlebus testaceipes*
Tachinid flies	Tachinidae family
Trichogramma spp., egg parasites	*Trichogramma* spp.
Trioxys pallidus, walnut aphid parasite	*Trioxys pallidus*

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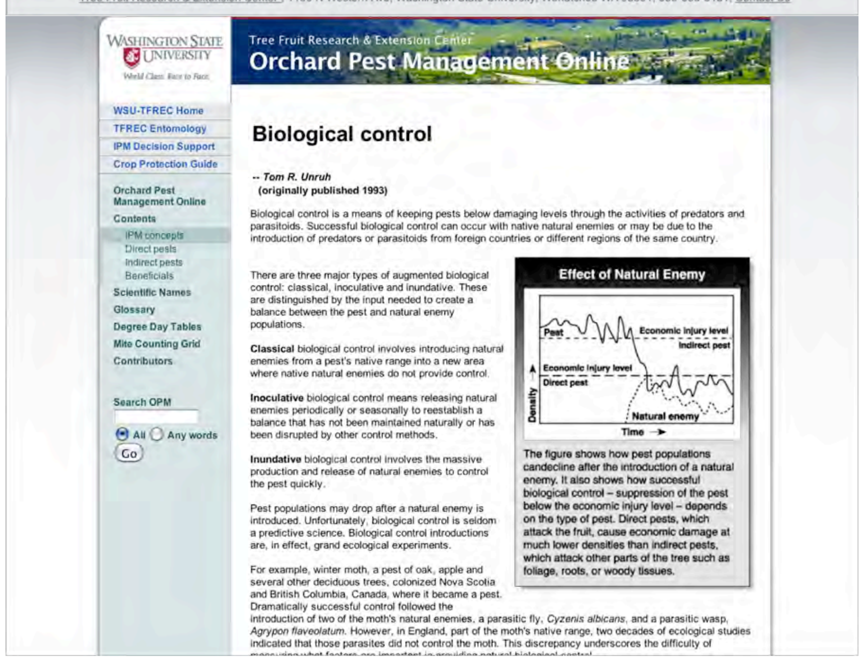

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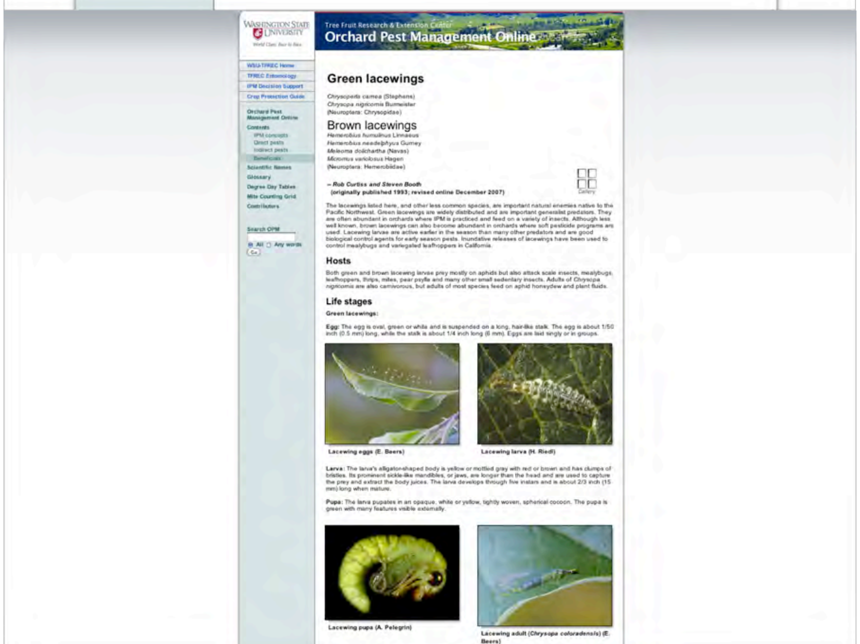

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Notes:

Notes:

Integrated Pest Management Resources

MICHIGAN STATE UNIVERSITY

Identifying natural enemies

Search

Scout our IPM resources

Resources for managing pests

- Christmas trees
- Field crops
- Fruit
- Home and yard
- Nursery and landscape
- Turfgrass
- Vegetable

Related pest diagnostic/ management programs

Diagnostic Services • Soil/Plant Nutrient Lab • Enviro-weather •Regional IPM Center • Pesticide safety • Organic: New Ag Network • Invasive species •Sustainable ag & food systems

Organizations

MSU ANR departments • MSU Extension • Site index •Contacts/permissions

Why recognize natural enemies and spiders?

These arthropods provide natural pest control by feeding on pest insects, including aphids, thrips, caterpillars and beetles that damage crops and other plants. The ability to distinguish natural enemies from pest insects will help you make informed pest control decisions.

The information here about natural enemies was developed for the publication **Identifying Natural Enemies in Field Crops** by Mary Gardiner, Christina DiFonzo, Michael Brewer and Takuji Noma. This is a pocket-sized guide for reference in the field. Although it is geared for field crops, it is appropriate for use in other crops, and by gardeners and by homeowners. To purchase a copy of the pocket-sized field guide, download the **order form** (pdf). Download **Adobe Acrobat Reader** to view pdf files.

Follow these links to learn about specific insects within these major groups of natural enemies and spiders:

- Beetles
- Lacewings
- Parasitoids
- Ants
- True bugs
- Predatory flies
- Spiders

Encourage natural enemies by planting native Michigan plants
Natural enemies and bees need pollen and nectar to survive. MSU is studying native Michigan flowering plants that can provide these resources for farmers and gardeners throughout the growing season. Planting these native Michigan perennials adjacent to crops could help increase the abundance of these insects over the long-term, leading to less need for pesticide sprays and greater fruit set and yield. Learn more at the **Enhancing Beneficial Insects with Native Plants** web site.

Lady beetles and other natural enemies have been proven to significantly decrease populations of soybean aphids in the Midwest.

The **MSU IPM Program** maintains this site as an access point to pest management information at MSU. The IPM Program is administered within the **Department of Entomology**, fueled by research from the **Michigan Agricultural Experiment Station**, delivered to citizens through **MSU Extension**, and proud to be a part of **Project GREEEN**.
Email the web developer.

Notes:

OSU Oregon State University

Find An Expert | OSU Extension | College of Ag Science | Pest Diagnosis |

INTEGRATED PLANT PROTECTION CENTER

Links

- IPPC Home
- Our Mission
- IPPC Staff
- IPPC Programs
- IPM at OSU
- IPM in the USA
- International Links

Search Here!

Quick Links

- Pest and Crop Models
- Pest Management Strategic Plans and IR-4 Project
- PNW Insect Management Conference
- Pesticide Safety and IPM Education
- Pesticides: Environmental Toxicology and Risk Assessment
- IPM Self-Study Resources
- On-Line IPM Handbooks
- iSNAP Program
- Farmscaping for Beneficials
- IPMnet NEWS
- Employment Opportunities with IPPC

NEWS

Assessing Beneficial Insect Habitat on Your Farm - September 1

Conservation Biological Control Brochure

OSU Drift Management Factsheet

English (high resolution) - (low resolution) **Spanish** (high resolution) - (low resolution)

Natural Enemy Pocket ID Guide

A small fishing village near the Senegal River. This is one of the study sites for a multi-donor, FAO (UN) coordinated program in which the IPPC plays a key role in investigating the fate and behavior of pesticides and the human and environmental risks associated with these chemicals. Methods developed within this project should feed back to the Pacific Northwest, where pesticide contamination of surface waters is also a concern.

Temporary Links

Model IPM Plan for Oregon Schools

Spotted wing *Drosophila* Information

Introductory Snapshot of IPPC Program

Plants for Pollinators (and Other Beneficials) in Oregon

Growers sampling beneficial insects on a "Farmscaping for Beneficials" program farm walk at Persephone Farm, Lebanon, Oregon.

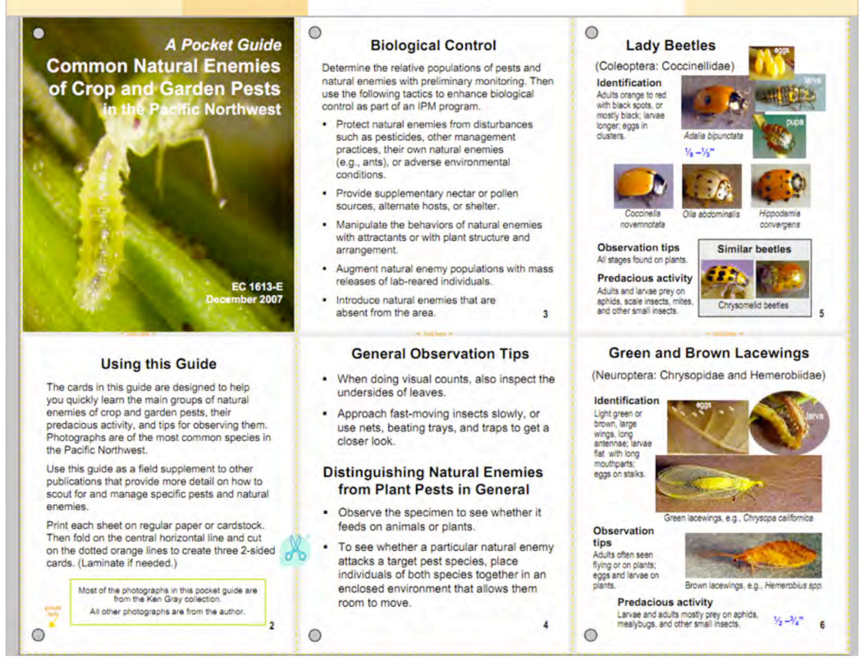
Archives

News

Temporary Links

Photos

Notes:



A Pocket Guide
Common Natural Enemies of Crop and Garden Pests in the Pacific Northwest

EC 1613-E
December 2007

Biological Control

Determine the relative populations of pests and natural enemies with preliminary monitoring. Then use the following tactics to enhance biological control as part of an IPM program.

- Protect natural enemies from disturbances such as pesticides, other management practices, their own natural enemies (e.g., ants), or adverse environmental conditions.
- Provide supplementary nectar or pollen sources, alternate hosts, or shelter.
- Manipulate the behaviors of natural enemies with attractants or with plant structure and arrangement.
- Augment natural enemy populations with mass releases of lab-reared individuals.
- Introduce natural enemies that are absent from the area.

3

Lady Beetles

(Coleoptera: Coccinellidae)

Identification
Adults orange to red with black spots, or mostly black; larvae longer; eggs in clusters.

eggs
larva
pupa
Adalia bipunctata
⅛–⅓"
Coccinella novemnotata
Olla abdominalis
Hippodamia convergens

Observation tips
All stages found on plants.

Predacious activity
Adults and larvae prey on aphids, scale insects, mites, and other small insects.

Similar beetles
Chrysomelid beetles

5

Using this Guide

The cards in this guide are designed to help you quickly learn the main groups of natural enemies of crop and garden pests, their predacious activity, and tips for observing them. Photographs are of the most common species in the Pacific Northwest.

Use this guide as a field supplement to other publications that provide more detail on how to scout for and manage specific pests and natural enemies.

Print each sheet on regular paper or cardstock. Then fold on the central horizontal line and cut on the dotted orange lines to create three 2-sided cards. (Laminate if needed.)

Most of the photographs in this pocket guide are from the Ken Gray collection.
All other photographs are from the author.

2

General Observation Tips

- When doing visual counts, also inspect the undersides of leaves.
- Approach fast-moving insects slowly, or use nets, beating trays, and traps to get a closer look.

Distinguishing Natural Enemies from Plant Pests in General

- Observe the specimen to see whether it feeds on animals or plants.
- To see whether a particular natural enemy attacks a target pest species, place individuals of both species together in an enclosed environment that allows them room to move.

4

Green and Brown Lacewings

(Neuroptera: Chrysopidae and Hemerobiidae)

Identification
Light green or brown, large wings, long antennae; larvae flat with long mouthparts; eggs on stalks.

eggs
larva
Green lacewings, e.g., *Chrysopa californica*

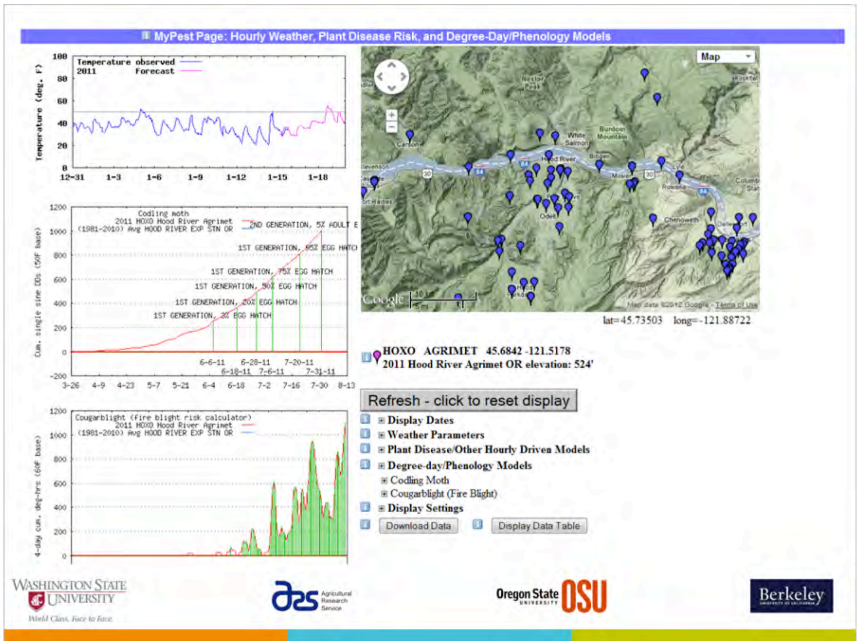
Observation tips
Adults often seen flying or on plants; eggs and larvae on plants.

Brown lacewings, e.g., *Hemerobius* spp.

Predacious activity
Larvae and adults mostly prey on aphids, mealybugs, and other small insects.

½–¾"

6



Notes:

Pacific Northwest Insect Management Handbook

http://pnwpest.org/pnw/insects

Chapter: Tree Fruit Section: Pear

Pear—Pear psylla

(Cacopsylla pyricola) **ID photos:** fact page (pdf):

Pest description and crop damage Pear psylla is one of the major pear pests in commercial orchards.

The adult resembles a miniature cicada. Adults have two distinct forms, a summer and winter form, which differ in appearance. Winterform adults are 0.1 inch long, dark in appearance, with transparent wings held rooflike over the body. Summerform adults are 0.08 inch long, greenish to brown, with a similar wing appearance to winterform. The nymphs pass through five growth stages, each stage being larger, flatter, and more oval than the last. The first stage is creamy yellow, the last is dark green or brown. All stages have conspicuous red eyes. During the first three stages, the nymphs are encased in a drop of honeydew. Nymphs and adults suck plant juices, producing honeydew that drips onto leaves and fruit. This encourages growth of sooty mold, which causes russetting of the skin. Blackening and burning of leaf tissue also is typical of psylla infestations. Large numbers of psylla can stunt and defoliate trees and cause fruit drop.

Biology and life history Pear psylla overwinter in a dormant state as winterform adults on a variety of fruit trees. They return to pears and begin laying eggs at bud swell. The eggs are shaped like grains of rice and are yellow-orange at maturity. These are laid at the base of buds and in other rough places on small twigs. Egg laying continues for some time. Later eggs are laid along leaf midveins and petioles, and on stems and sepals of blossoms. The nymphs hatch and feed on the opening blossoms and young leaves, forming droplets of honeydew on both leaf surfaces. There may be two to three generations before the winterform generation appears in the fall.

Scouting and thresholds Monitor adults by placing a white cloth or paper under a limb and then jarring the limb to knock them onto the paper, starting in March. Check with a hand lens for eggs and nymphs on young shoots and leaves.

Management—biological control

A number of natural enemies attack psylla, including parasitic wasps, adults and larvae of ladybeetles, lacewings, and earwigs, as well as predacious plant bugs and minute pirate bugs. If natural enemies are conserved within the orchard, biological control of this pest often can be significant. Temperatures above 90°F may inhibit egg-laying and desiccate nymphs.

Management—cultural control

Avoid promoting unnecessary vigor with excess fertilizer and/or water. Remove suckers from the interior of the trees, which removes psylla eggs and nymphs and increases spray coverage.

Management—chemical control: HOME USE

Dormant-season spray

Use enough water to cover all of the tree thoroughly including small limbs and shoots. Spray timing can vary from early February to late March depending on location. Apply only during dormant or delayed-dormant period.

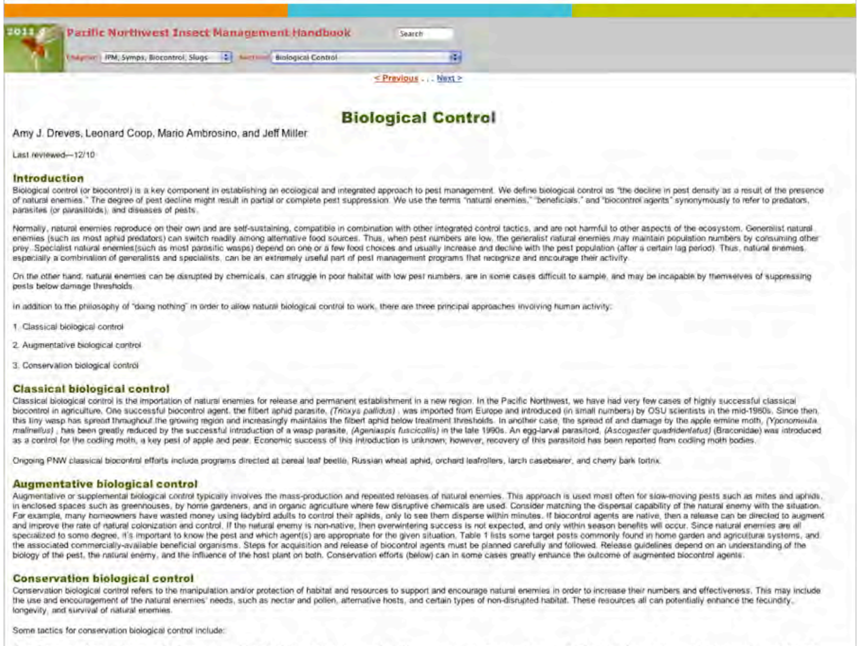
1. lime sulfur mixed with superior-type oil

2. superior-type oil

Growing-season spray

1. azadirachtin (neem extract)—If control is not satisfactory, add minimal rates of superior oil. Products containing neem extract may be phytoxic to some pear cultivars.

Notes:



Pacific Northwest Insect Management Handbook

Chapter: IPM, Symps, Biocontrol, Slugs Section: Biological Control

< Previous . . . Next >

Biological Control

Amy J. Dreves, Leonard Coop, Mario Ambrosino, and Jeff Miller

Last reviewed—12/10

Introduction

Biological control (or biocontrol) is a key component in establishing an ecological and integrated approach to pest management. We define biological control as "the decline in pest density as a result of the presence of natural enemies." The degree of pest decline might result in partial or complete pest suppression. We use the terms "natural enemies," "beneficials," and "biocontrol agents" synonymously to refer to predators, parasites (or parasitoids), and diseases of pests.

Normally, natural enemies reproduce on their own and are self-sustaining, compatible in combination with other integrated control tactics, and are not harmful to other aspects of the ecosystem. Generalist natural enemies (such as most aphid predators) can switch readily among alternative food sources. Thus, when pest numbers are low, the generalist natural enemies may maintain population numbers by consuming other prey. Specialist natural enemies(such as most parasitic wasps) depend on one or a few food choices and usually increase and decline with the pest population (after a certain lag period). Thus, natural enemies, especially a combination of generalists and specialists, can be an extremely useful part of pest management programs that recognize and encourage their activity.

On the other hand, natural enemies can be disrupted by chemicals, can struggle in poor habitat with low pest numbers, are in some cases difficult to sample, and may be incapable by themselves of suppressing pests below damage thresholds.

In addition to the philosophy of "doing nothing" in order to allow natural biological control to work, there are three principal approaches involving human activity:

1. Classical biological control

2. Augmentative biological control

3. Conservation biological control

Classical biological control

Classical biological control is the importation of natural enemies for release and permanent establishment in a new region. In the Pacific Northwest, we have had very few cases of highly successful classical biocontrol in agriculture. One successful biocontrol agent, the filbert aphid parasite, *(Trioxys pallidus)*, was imported from Europe and introduced (in small numbers) by OSU scientists in the mid-1980s. Since then, this tiny wasp has spread throughout the growing region and increasingly maintains the filbert aphid below treatment thresholds. In another case, the spread of and damage by the apple ermine moth, *(Yponomeuta malinellus)*, has been greatly reduced by the successful introduction of a wasp parasite, *(Ageniaspis fuscicollis)* in the late 1990s. An egg-larval parasitoid, *(Ascogaster quadridentatus)* (Braconidae) was introduced as a control for the codling moth, a key pest of apple and pear. Economic success of this introduction is unknown; however, recovery of this parasitoid has been reported from codling moth bodies.

Ongoing PNW classical biocontrol efforts include programs directed at cereal leaf beetle, Russian wheat aphid, orchard leafrollers, larch casebearer, and cherry bark tortrix.

Augmentative biological control

Augmentative or supplemental biological control typically involves the mass-production and repeated releases of natural enemies. This approach is used most often for slow-moving pests such as mites and aphids, in enclosed spaces such as greenhouses, by home gardeners, and in organic agriculture where few disruptive chemicals are used. Consider matching the dispersal capability of the natural enemy with the situation. For example, many homeowners have wasted money using ladybird adults to control their aphids, only to see them disperse within minutes. If biocontrol agents are native, then a release can be directed to augment and improve the rate of natural colonization and control. If the natural enemy is non-native, then overwintering success is not expected, and only within season benefits will occur. Since natural enemies are all specialized to some degree, it's important to know the pest and which agent(s) are appropriate for the given situation. Table 1 lists some target pests commonly found in home garden and agricultural systems, and the associated commercially-available beneficial organisms. Steps for acquisition and release of biocontrol agents must be planned carefully and followed. Release guidelines depend on an understanding of the biology of the pest, the natural enemy, and the influence of the host plant on both. Conservation efforts (below) can in some cases greatly enhance the outcome of augmented biocontrol agents.

Conservation biological control

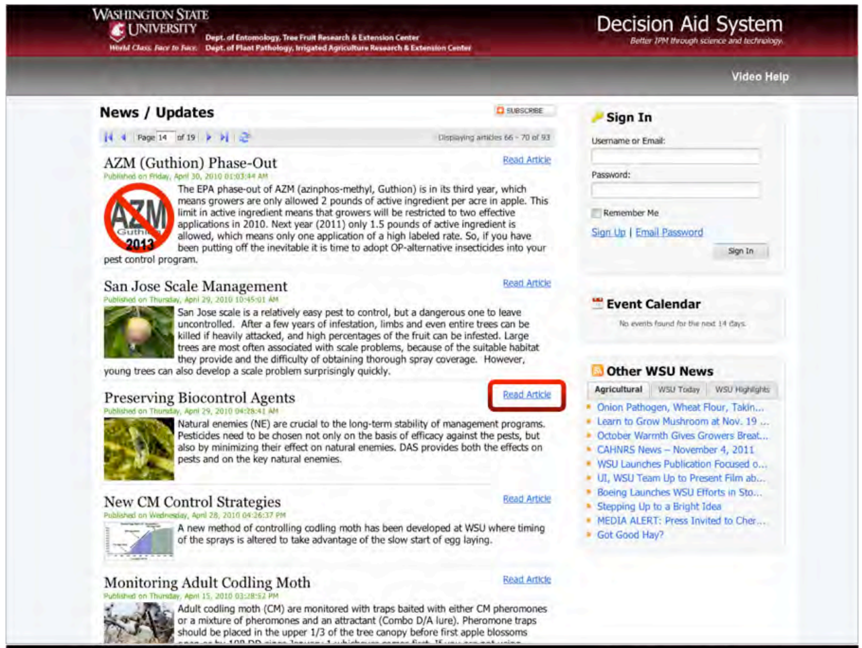
Conservation biological control refers to the manipulation and/or protection of habitat and resources to support and encourage natural enemies in order to increase their numbers and effectiveness. This may include the use and encouragement of the natural enemies' needs, such as nectar and pollen, alternative hosts, and certain types of non-disrupted habitat. These resources all can potentially enhance the fecundity, longevity, and survival of natural enemies.

Some tactics for conservation biological control include:

Careful use of pesticides and tillage to avoid disturbing natural enemies. Many pests are "secondary pests" in that they only reach economic pest levels

Notes:

Notes:



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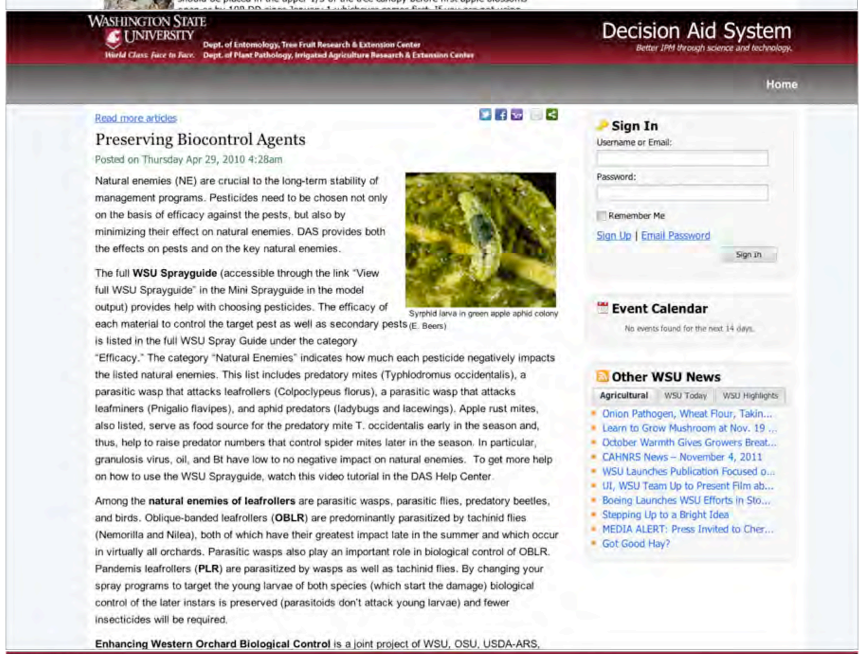

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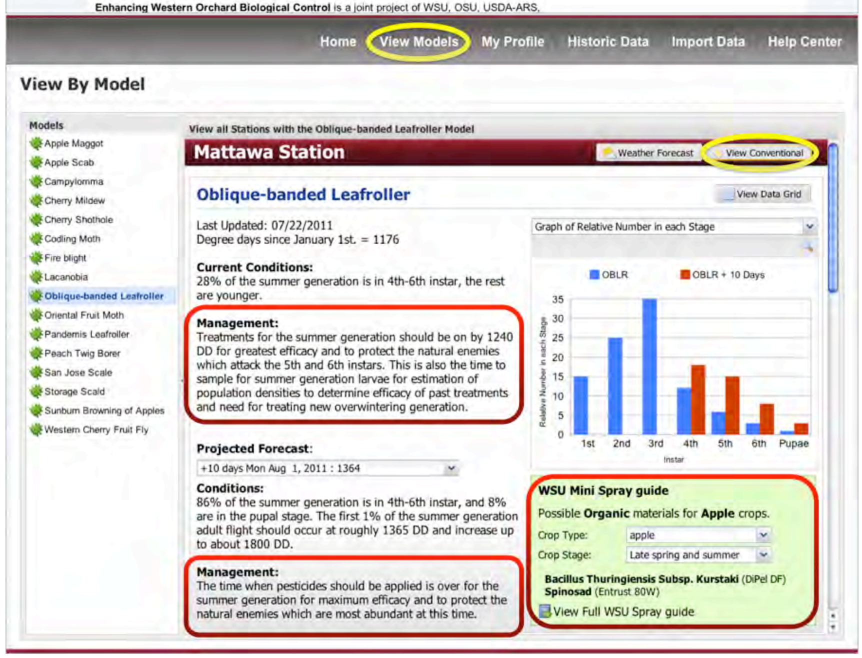
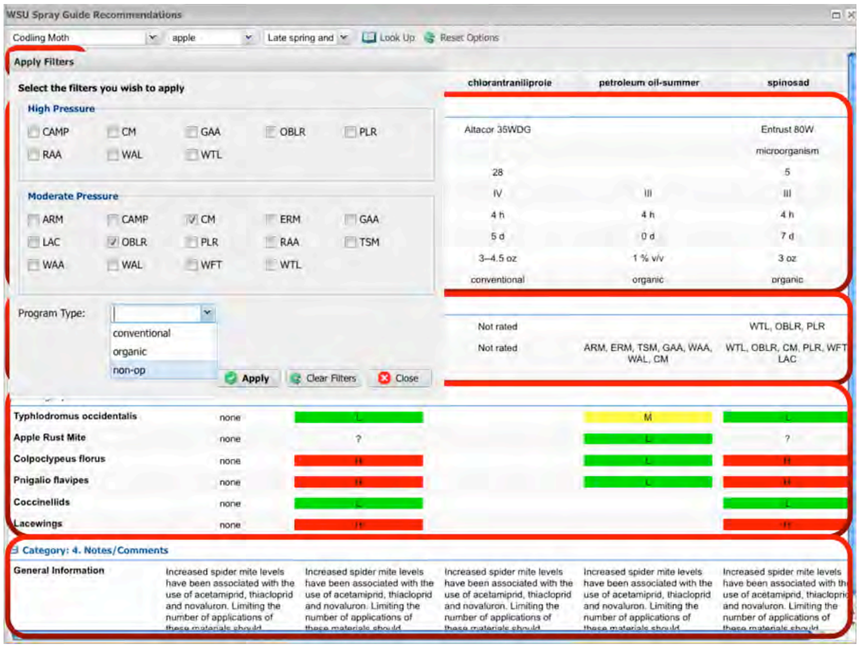




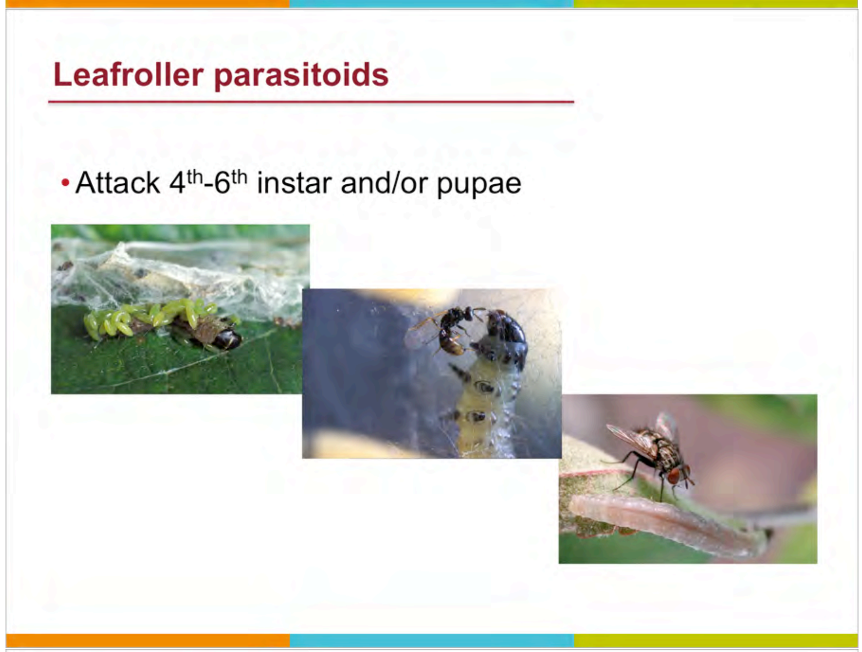
WSU Spray Guide Recommendations
Codling Moth
apple
Late spring and
Look Up
Reset Options
Apply Filters
Select the filters you wish to apply
High Pressure
CAMP CM GAA OBLR PLR
RAA WAL WTL
Moderate Pressure
ARM CAMP CM ERM GAA
LAC OBLR PLR RAA TSM
WAA WAL WFT WTL
Program Type:
conventional
organic
non-op
Apply
Clear Filters
Close
chlorantraniliprole
petroleum oil-summer
spinosad
Altacor 35WDG
Entrust 80W
microorganism
Typhlodromus occidentalis
Apple Rust Mite
Colpoclypeus florus
Pnigalio flavipes
Coccinellids
Lacewings
Category: 4. Notes/Comments
General Information
Increased spider mite levels have been associated with the use of acetamiprid, thiacloprid and novaluron. Limiting the number of applications of

Notes:

Presentation 8: Exercise - Windows of Opportunity

Notes:

Notes:



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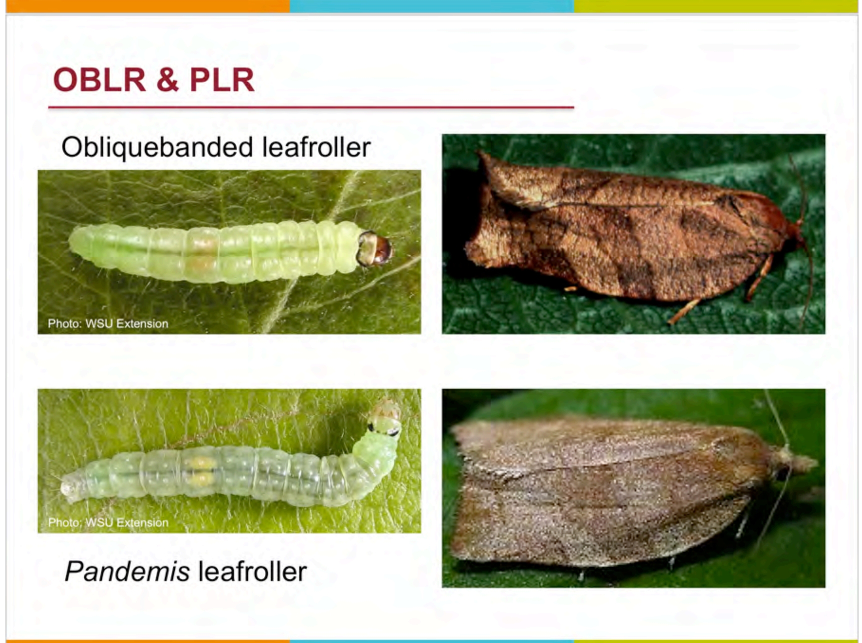
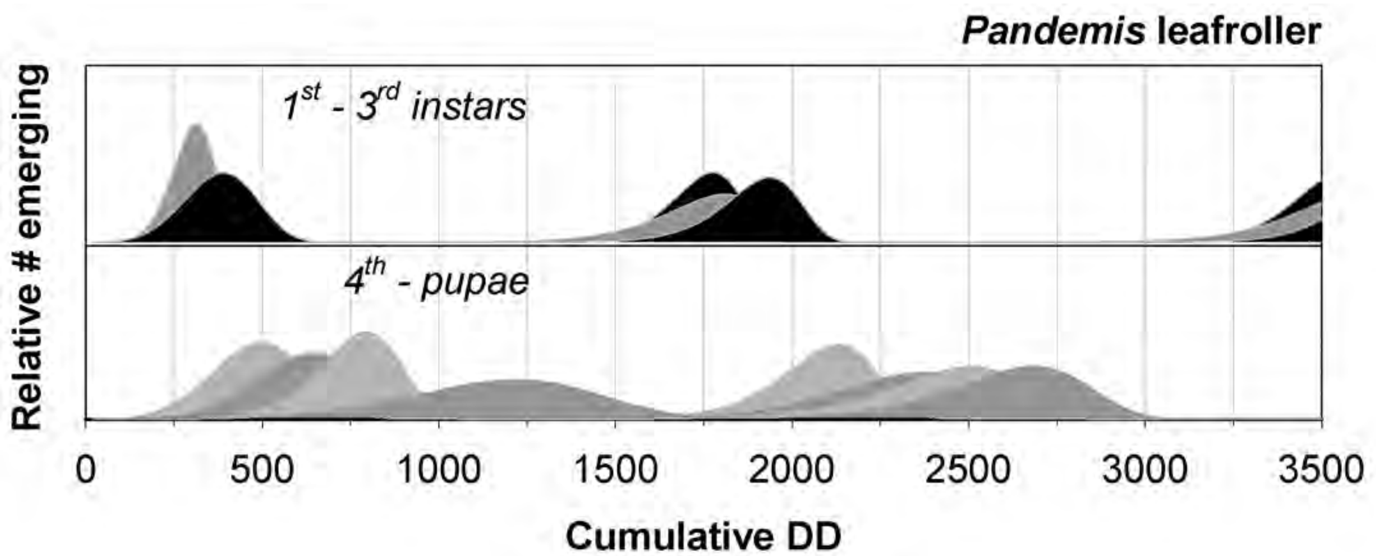


Short Exercise Task #1: Windows of Opportunity for PLR & OBLR

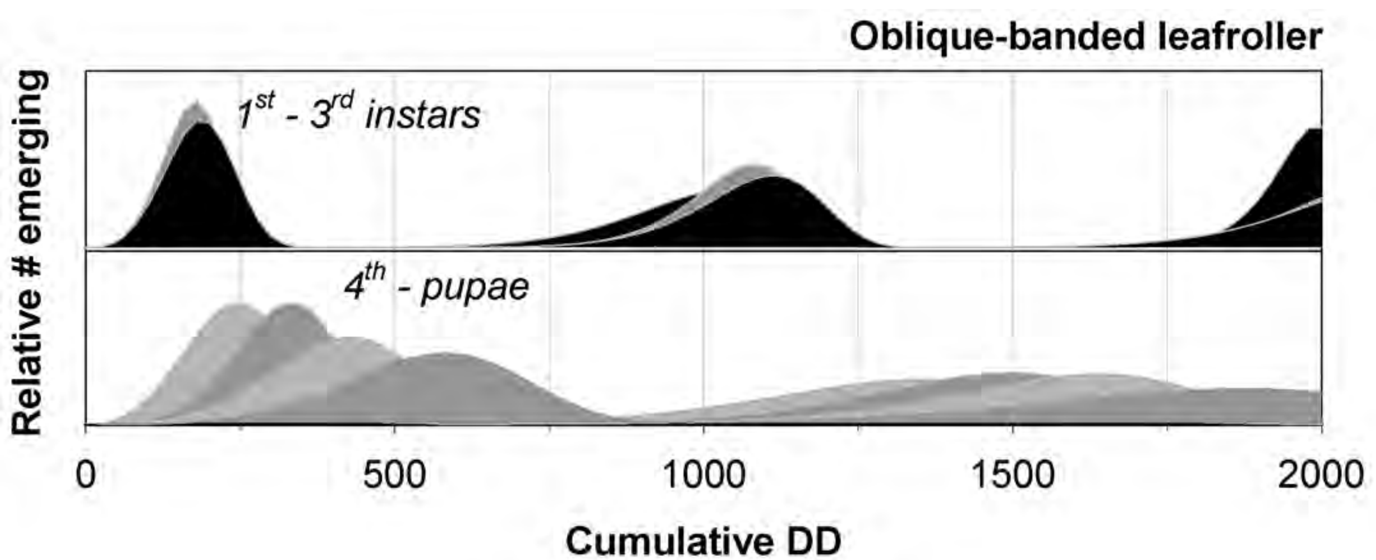
Task 1a: On the chart below, mark when parasitoids are present and when you should avoid sprays; then mark when sprays can be applied without harming PLR parasitoids.

PLR Phenology



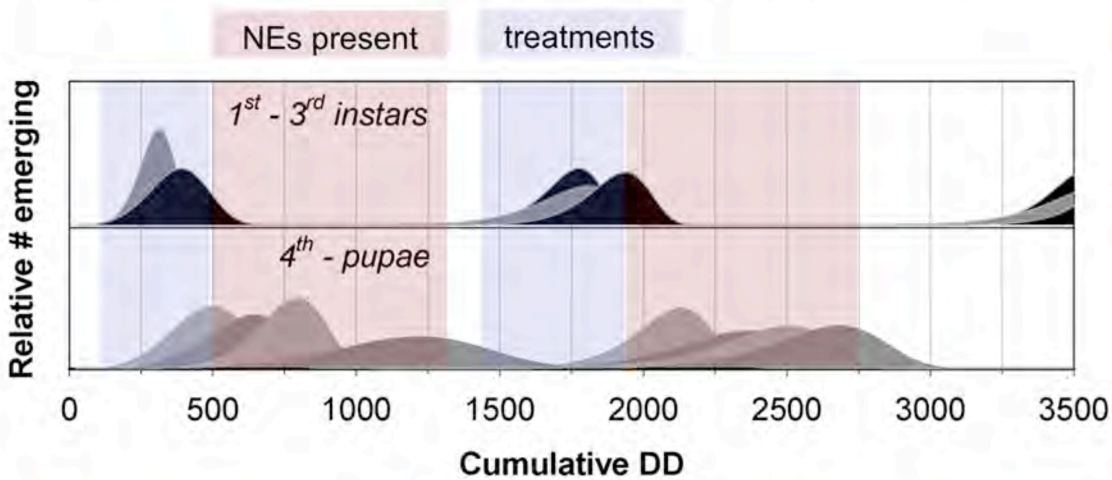
Task 1b: On the chart below, mark when parasitoids are present and when you should avoid sprays; then mark when sprays can be applied without harming OBLR parasitoids.

OBLR Phenology

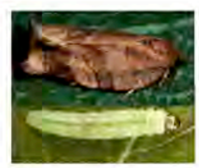


Windows of Opportunity for PLR

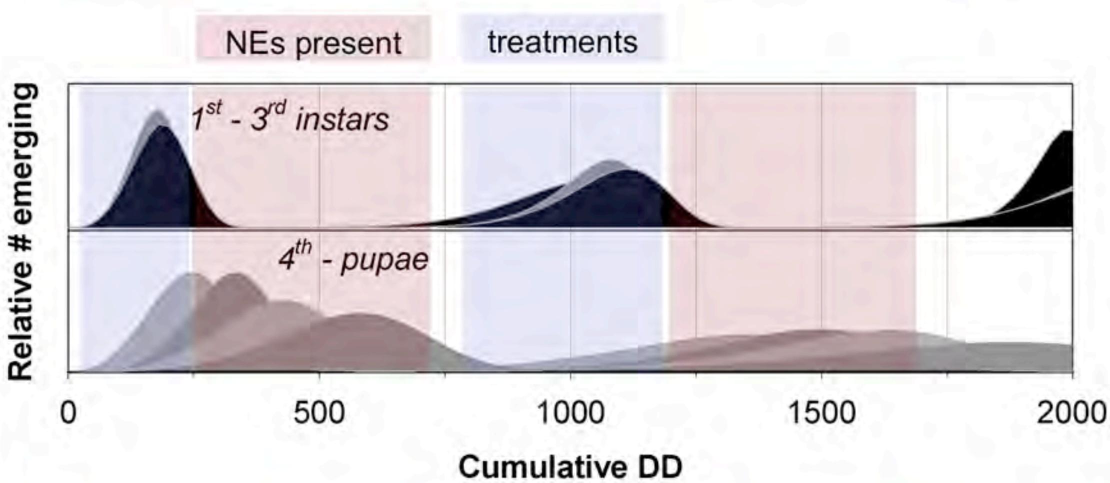
- 29% mortality in overwintering gen., 45% in summer gen.



Windows of Opportunity for OBLR



- 19% mortality in overwintering gen., 29% in summer gen.



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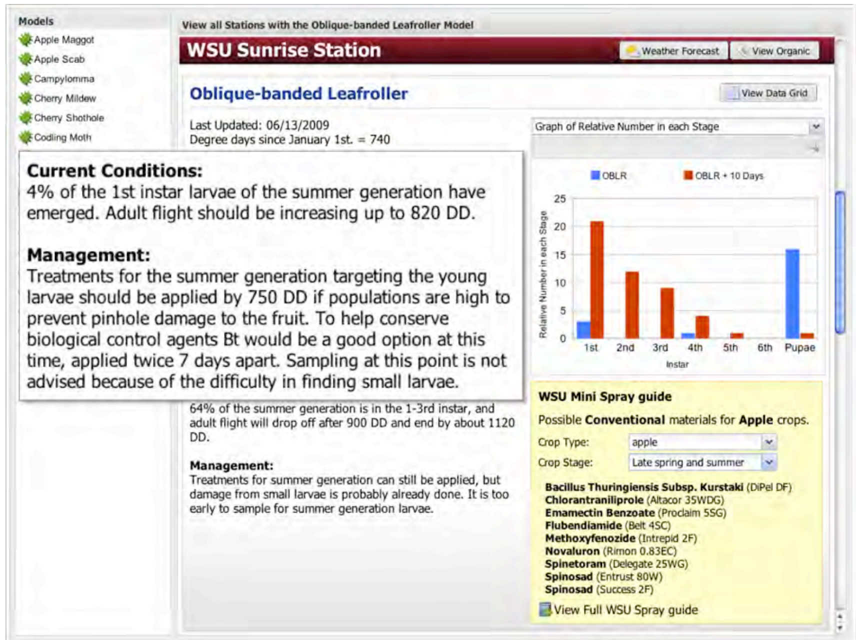

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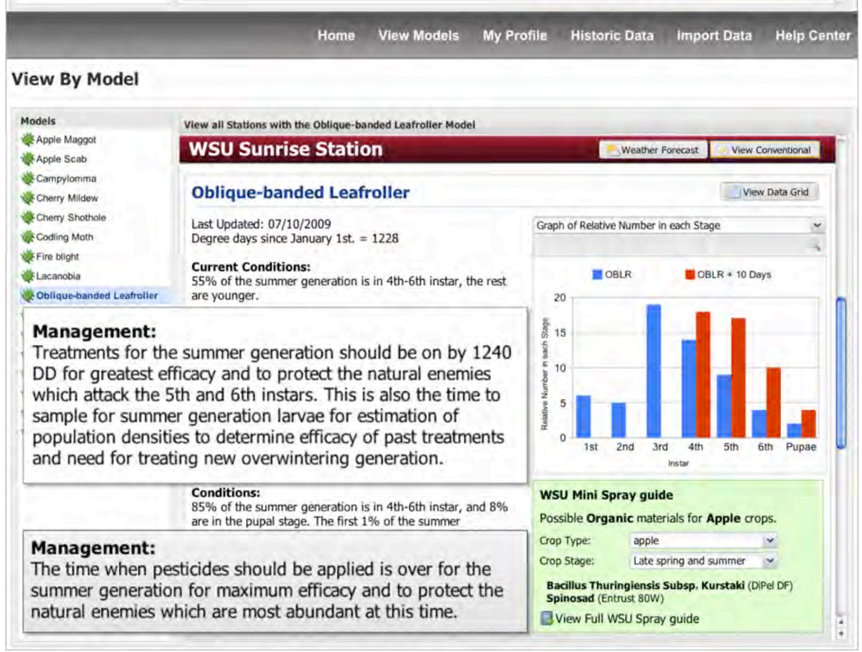


Notes:

When and how to monitor leafrollers

- Pheromone traps
- Sampling (summer generation)
  - 25 shoots from 1 tree per 1.5 acres, count # of larvae
    - larvae in upper half of tree, esp. when more than 10 feet tall
  - Retreat when more than 2% of shoots with live larvae
- Overwintering generation
  - between green tip and tight cluster – collect buds (6 buds each from 25 trees in 5 acres) – examine under magnification

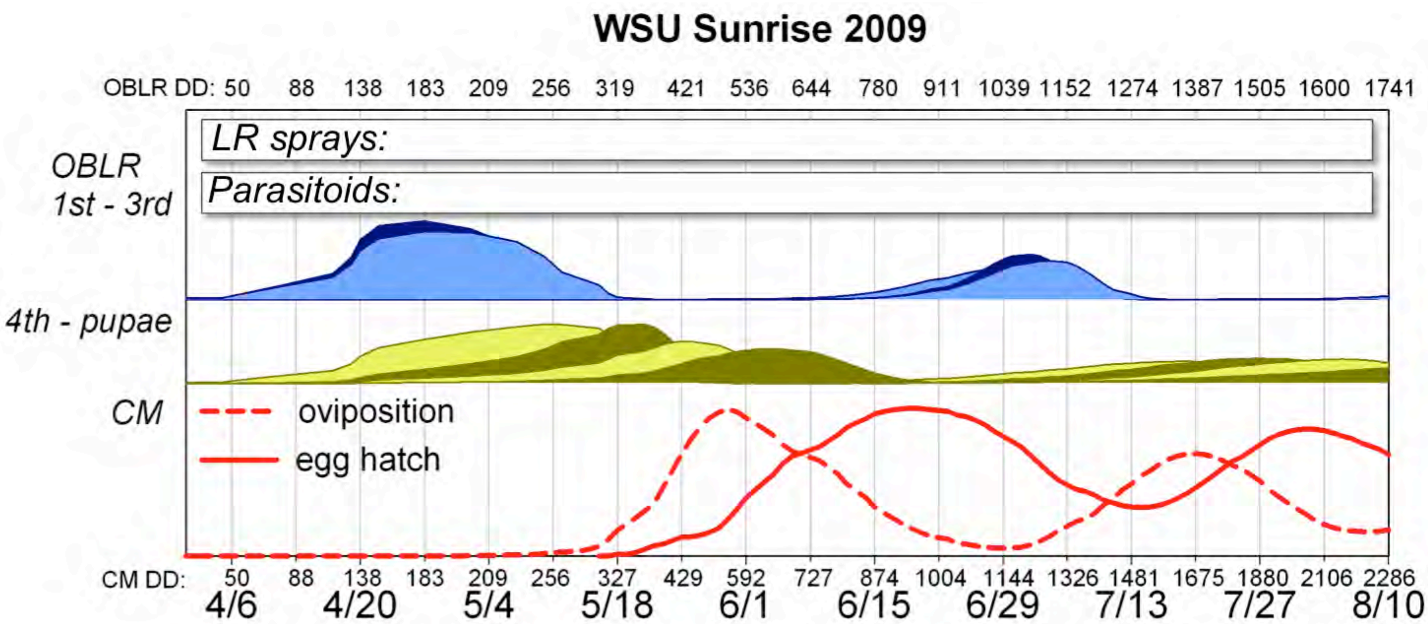
Washington State University
Oregon State University
Berkeley

Short Exercise Task #2: Timing of LR control treatments

Task 2a: On the chart below, mark the period when LR parasitoids are active in the orchard.

Task 2b: On the chart below, mark when OBLR treatments are recommended using DAS (for overwintering and summer generations). When are LR parasitoids affected?

Use the information from the DAS screen shots on the next page to complete this exercise.



View all Stations with the Oblique-banded Leafroller Model

WSU Sunrise Station

Weather Forecast | View Organic

Oblique-banded Leafroller

View Data Grid

Last Updated: 05/11/2009
Degree days since January 1st. = 256

Current Conditions:
About 33% of the overwintering generation is in the 4th instar and 22% are in the 5th instar.

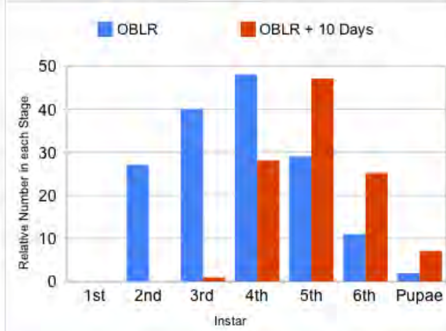
Management:
Sample to determine population levels between 180-280 DD. If treatments are needed, apply before 370 DD so that less than 10% of the overwintering generation is in the pupal stage (pupae are insensitive to the pesticide); if using Esteem the first spray must be on between 250-300 DD. For every 20 DD delay in the application, the portion of the population controlled decreases by 3-5%.

Projected Forecast:
+10 days Thu May 21, 2009 : 342

Conditions:
69% of the overwintering generation is in the 5th and 6th instars. 8% of the population is in the pupal stage, and first adults should appear at roughly 550 DD.

Management:
If treatments are needed, apply before 370 DD so that less than 10% of the population is in the pupal stage (pupae are insensitive to the pesticide); if using Esteem the first spray must be on between 250-300 DD. For every 20 DD delay in the application, the portion of the population controlled by Esteem decreases by 3-5%. If sprays are not required for the first generation, sampling can be continued during this period to help determine if the summer generation larvae need to be treated.

Graph of Relative Number in each Stage



WSU Mini Spray guide

Possible **Conventional** materials for **Apple** crops.

Crop Type: apple
Crop Stage: Bloom

Bacillus Thuringiensis Subsp. Kurstaki (DiPel DF)
Methoxyfenozide (Intrepid 2F)

View Full WSU Spray guide

View all Stations with the Oblique-banded Leafroller Model

WSU Sunrise Station

Weather Forecast | View Organic

Oblique-banded Leafroller

View Data Grid

Last Updated: 06/10/2009
Degree days since January 1st. = 675

Current Conditions:
2% of the 1st instar larvae of the summer generation have emerged. Adult flight should be increasing up to 820 DD.

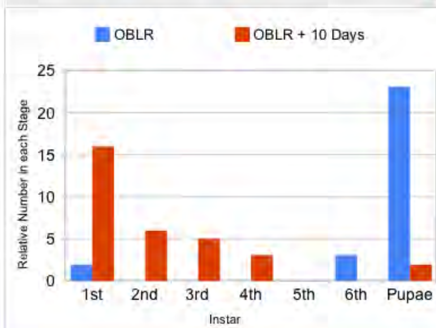
Management:
Treatments for the summer generation targeting the young larvae should be applied by 750 DD if populations are high to prevent pinhole damage to the fruit. To help conserve biological control agents Bt would be a good option at this time, applied twice 7 days apart. Sampling at this point is not advised because of the difficulty in finding small larvae.

Projected Forecast:
+10 days Sat Jun 20, 2009 : 887

Conditions:
53% of the summer generation is in the 1-3rd instar, and adult flight will drop off after 900 DD and end by about 1120 DD.

Management:
Treatments for summer generation can still be applied, but damage from small larvae is probably already done. It is too early to sample for summer generation larvae.

Graph of Relative Number in each Stage



WSU Mini Spray guide

Possible **Conventional** materials for **Apple** crops.

Crop Type: apple
Crop Stage: Late spring and summer

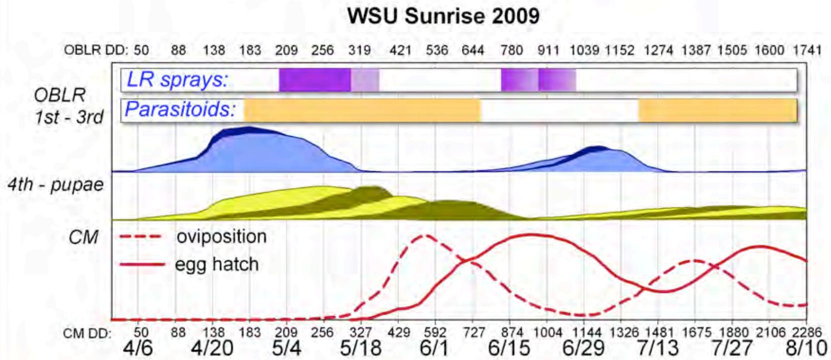
Bacillus Thuringiensis Subsp. Kurstaki (DiPel DF)
Chlorantraniliprole (Altacor 35WDG)
Emamectin Benzoate (Proclaim 5SG)
Flubendiamide (Belt 4SC)
Methoxyfenozide (Intrepid 2F)
Novaluron (Rimon 0.83EC)
Spinetoram (Delegate 25WG)
Spinosad (Entrust 80W)
Spinosad (Success 2F)

View Full WSU Spray guide

Also see pages 198 & 199 in this workbook

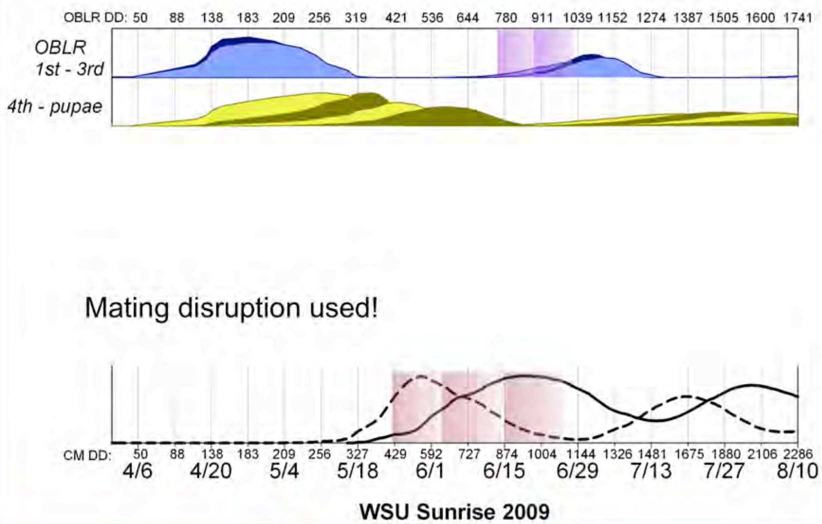
Timing of LR control treatments

- **WOO: shift LR treatment to *summer generation***
  (and use Bt)



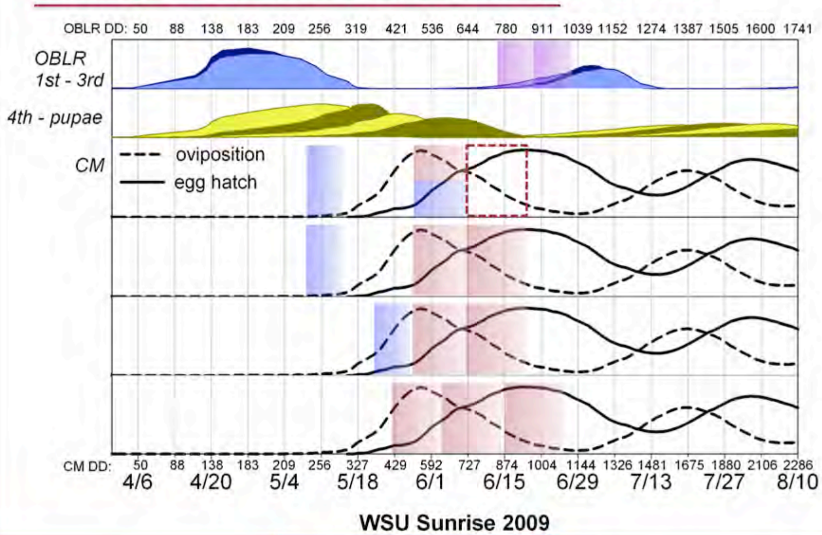
Notes:

Timing of CM and OBLR control treatments



Notes:

Timing of CM and OBLR control treatments



Notes:

(A larger version of this chart can be found in the Resources of this workbook on page 202.)

Notes:

LR (larva) LR&CM (egg)	CM (egg)	CM (larva)	CM (larva)	CM (larva)	CM (larva)	CM (larva)
Petal fall 225-275 DD (50-100 DD pbf)	375 DD (200 DD pbf)	1st cover 425 DD (250 DD pbf)	Delayed 1st cover 525 DD (350 DD pbf)	2nd cover 625-675 DD (450-500 DD pbf)	Delayed 2nd cover 725-825 DD (550-650 DD pbf)	3rd cover 875-925 DD (700-750 DD pbf)
Proclaim Success Delegate Belt Bt	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	→	Delegate Entrust Altacor Assail Calypso Intrepid virus
Proclaim Success Delegate Belt Bt	→ Oil	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	
Altacor Intrepid Rimon Esteem	→	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	→	Delegate Entrust Altacor Assail Calypso Intrepid virus	
Altacor Intrepid Rimon Esteem	*Tank mix* →	→	Delegate Entrust Assail Calypso virus + Altacor Intrepid Rimon Esteem		May not need 2nd cover	

pbf = post biofix

Source: Pest Management Transition Project Handbook (*http://pmtp.wsu.edu/handbook.html*)

Notes:

Timing of CM and OBLR control treatments

Protect natural enemies:

- **Delay CM cover sprays (larvicides) by treating eggs;**
  - ➥ **Decreases # of sprays**
- **Tank-mix larvicides and ovicides for 1st delayed cover spray**
  - ➥ **may not need 2nd delayed cover**

➥ **Fewer sprays to impact NEs**

Notes:

Windows of opportunities: secondary pests

- Why is it more complicated for aphids and mites?
  - Overlapping generations
  - ➥ no simple timing of stages as in LR
  - ➥ their predators and parasitoids can be present for longer periods

Windows of opportunities for generalists

- Why is it more complicated for predators?
  - Not as intimately linked to specific prey species and/or stage as parasitoids (generalists)
  - Different stages predatory
  - Phenology not fully known

Notes:

Summary – Windows of Opportunity

- LR management
  - OBLR/PLR: avoid pesticides during 4-6th instars & pupae
  - Shift LR sprays to summer generation (1st-3rd instars)
- CM management
  - Delay CM cover sprays (larvicides) by treating eggs
  - Tank-mix larvicides & ovicides for 1st delayed cover spray
- Overlapping generation & general predators add complexity
- Resources: DAS (das.wsu.edu)

Washington State University World Class. Face to Face. | das Agricultural Research Service | Oregon State University OSU | Berkeley

Notes:

Presentation 9: Effects of Pesticides on Natural Enemies

Notes:

Effect of Pesticides on Natural Enemies

Nick Mills, University of California, Berkeley

Betsy Beers, Washington State University, Wenatchee

Tom Unruh, USDA-ARS, Wapato

Peter Shearer, Oregon State University, Hood River

Notes:

Overview

- Why do pesticides impact natural enemies?
- Pesticides and natural enemies tested
- Experimental approach:
  laboratory bioassays and extrapolation
- Bioassay results
  acute and sublethal
- Ranking for field verification
- Summary

Notes:

What is IPM?

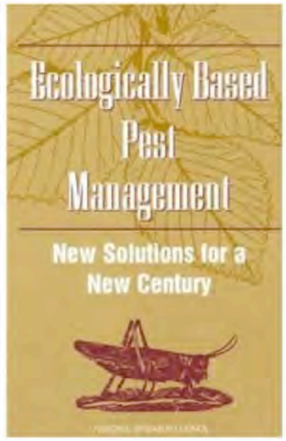
- Scheduling pesticide applications based on monitoring and economic thresholds

- Stern et al. (1959) 'The ideal material [pesticide] is not one that eliminates all individuals of the pest species . . . [It] is the one that shifts the balance back in favor of natural enemies'

What is IPM?

- NRC (1996) recommended use of Ecologically Based Pest Management

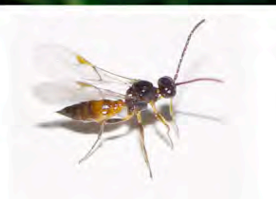
  which 'will seek to manage rather than eliminate pests' in ways that are 'profitable, safe, and durable'



Notes:

Natural enemy susceptibility to pesticides

- Natural enemies are more susceptible to pesticides than pests because:
  - they experience greater exposure due to great mobility
  - unlike plant pests they don't have general enzyme systems for detoxification



Notes:

Pesticides tested

- Fungicides – targeting powdery mildew/walnut blight

  Kumulus, Kocide-Manzate

- Insecticides – targeting codling moth

  Diamides - Altacor, Cyazypyr

  Spinosyn - Delegate

  Chitin synthesis inhibitor - Rimon

  Pyrethroid - Warrior

Notes:

Notes:

Natural enemies tested

- Mite predator
  Galendromus occidentalis
- Spiders
  Misumenops lepidus
  Pelegrina aeneola
- Green lacewing
  Chrysoperla carnea
- Psylla predator
  Deraeocoris brevis
- Aphid predator
  Hippodamia convergens
- Aphid parasitoids
  Aphelinus mali, Trioxys pallidus

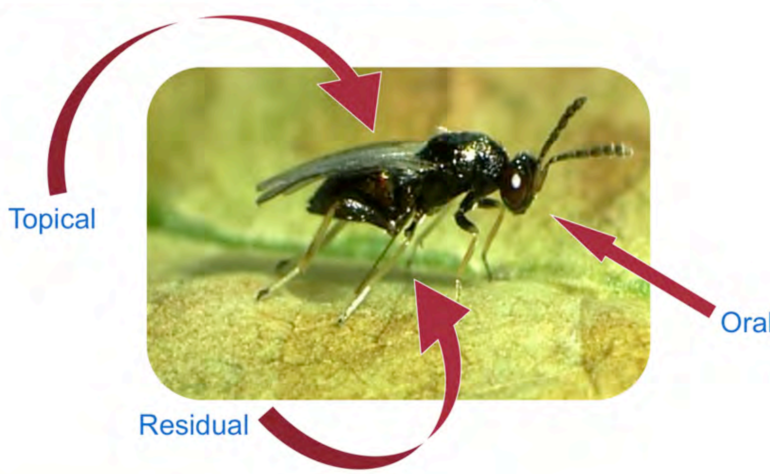
Notes:

Experimental approach

- Laboratory bioassays in simple glass arenas of direct (acute) and indirect (sublethal) effects of pesticides on natural enemies, incorporating multiple routes of exposure
- Extrapolation of the response of individuals to pesticides in lab bioassays to probable effects of natural enemy populations in the field

Notes:

Multiple routes of exposure



Probable effects in the field

➢ Why not avoid the difficulty of extrapolation and simply test effects on natural enemies directly in the field?

- Few materials can be tested simultaneously
- High cost
- Issues of scale (plot size) and replication
- Issues of whether natural enemies will be present

Notes:

Lab-based bioassays

Acute assays → Topical or residual exposure → Full field rate and 10% field rate → *Endpoint* - acute mortality after 48 h

Sublethal assays → Multiple modes of exposure → Highest rate with <75% acute mortality → *Endpoint* – population growth rate based on observed impacts on individual life history parameters

Notes:

Acute bioassays

- Topical or residual application with Potter tower
- Anaesthetize the natural enemies with CO2
- Natural enemies placed singly into glass arenas

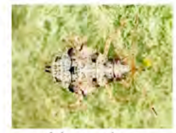
Notes:

Notes:

Sublethal bioassays

Adults
(Males and Females)

Multiple Routes of Exposure



Nymphs
(Second Instars)

Potter Spray Tower

Insects (Topical)
Arenas (Residual)

Drenched

Ephestia eggs [food] (Oral)
Green beans [moisture] (Oral)
Cheese cloth lids (Residual)

Environmental Growth Chamber

23°C, 60% RH, and 16:8 h (L:D)

Notes:

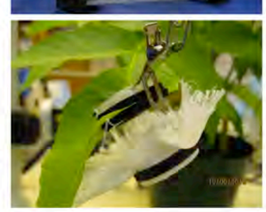
Endpoint measurements from bioassays

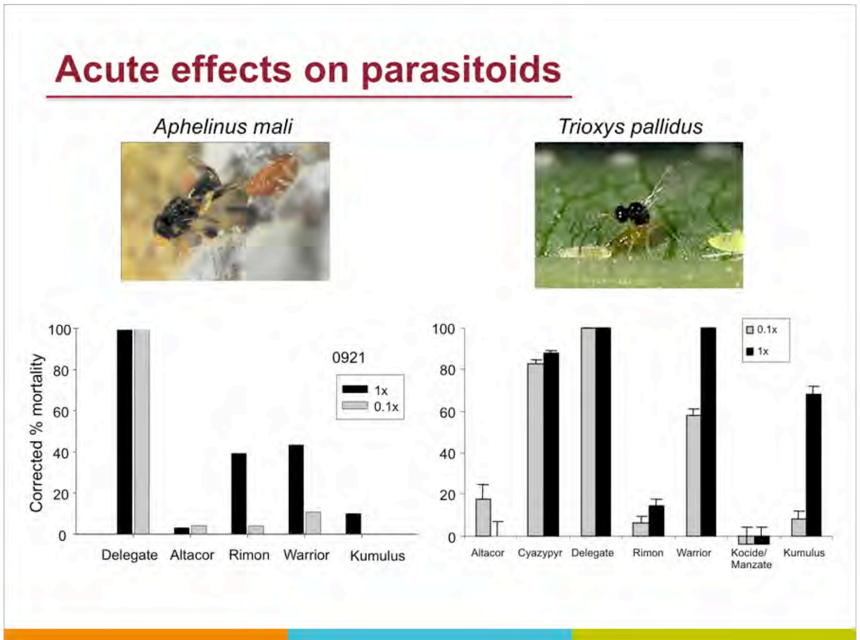
- Direct (acute) effect
  - Mortality within 48h of exposure
- Indirect (sublethal) effects
  - Reduced survivorship of adults or juveniles
  - Reduced per capita daily fecundity
  - Reduced egg hatch
  - Prolonged development time of juveniles
  - Altered sex ratio of progeny

Notes:

Extrapolation from Bioassays

- Direct effects
  - 48h acute mortality
- Indirect effects
  - A series of life history parameters
- Extrapolation
  - Demographic matrix models
  - Integrate mortality and life history measurements into a single index - population growth rate





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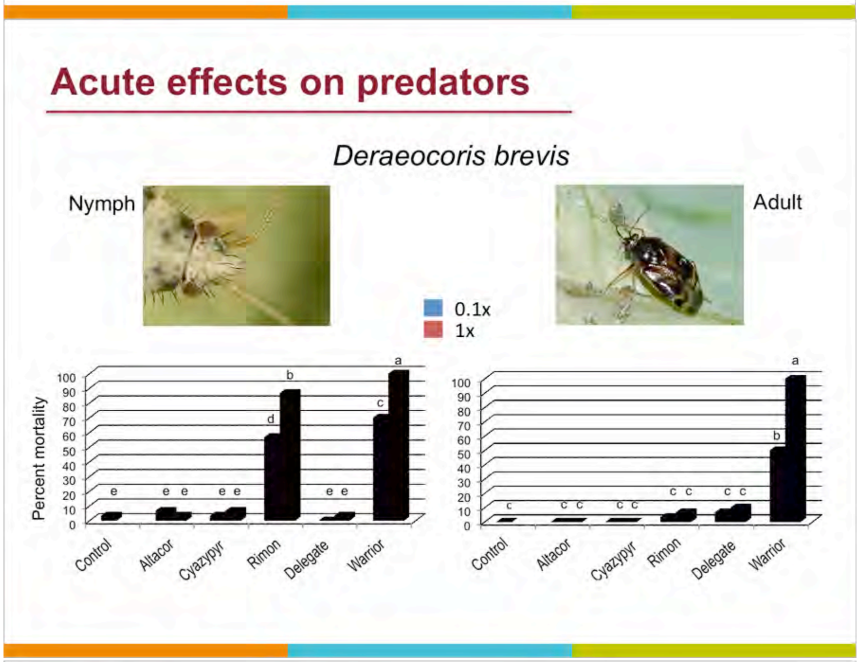

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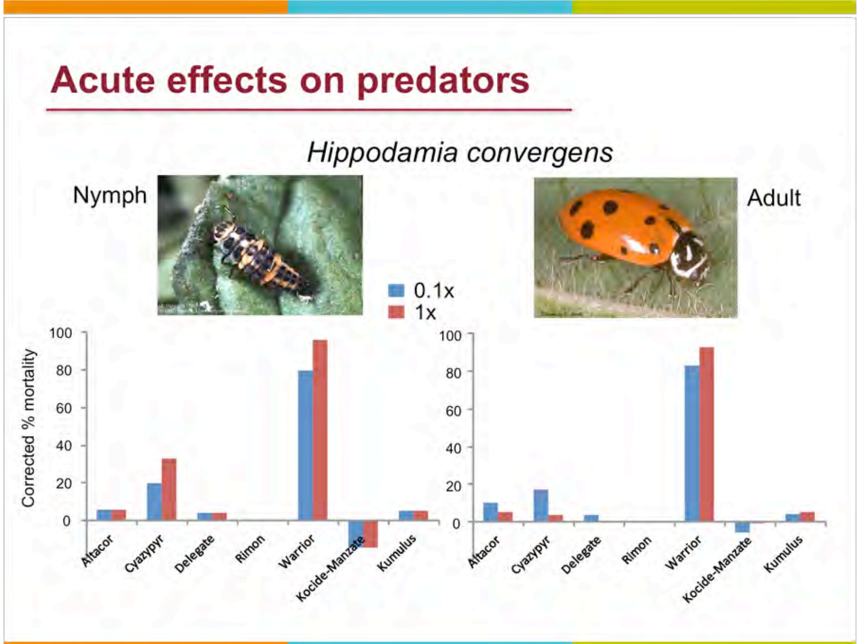

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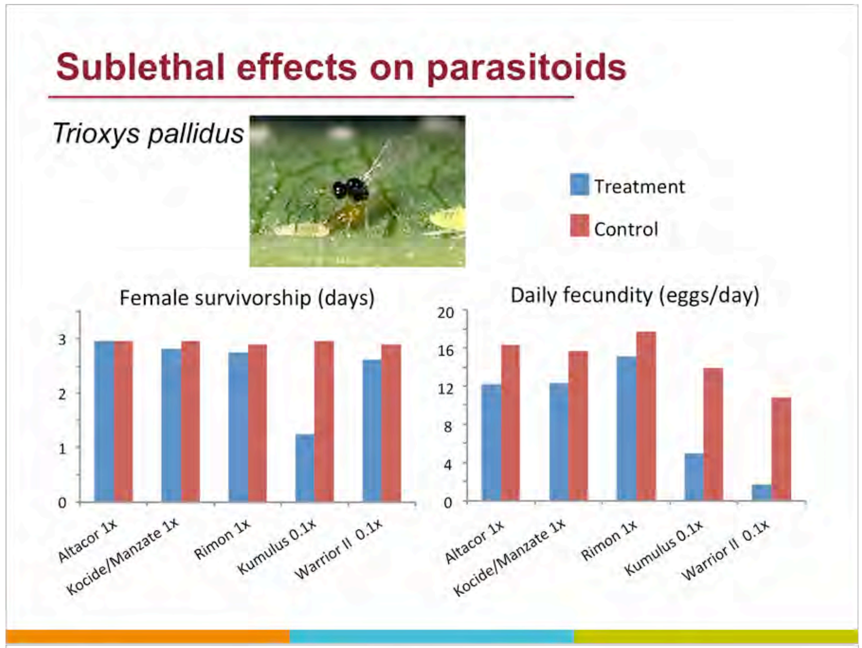

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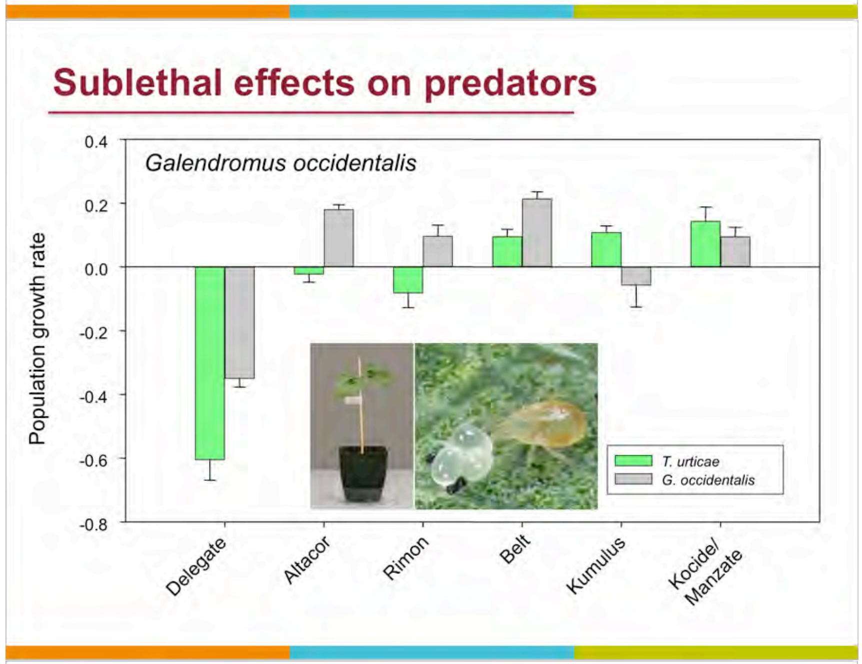

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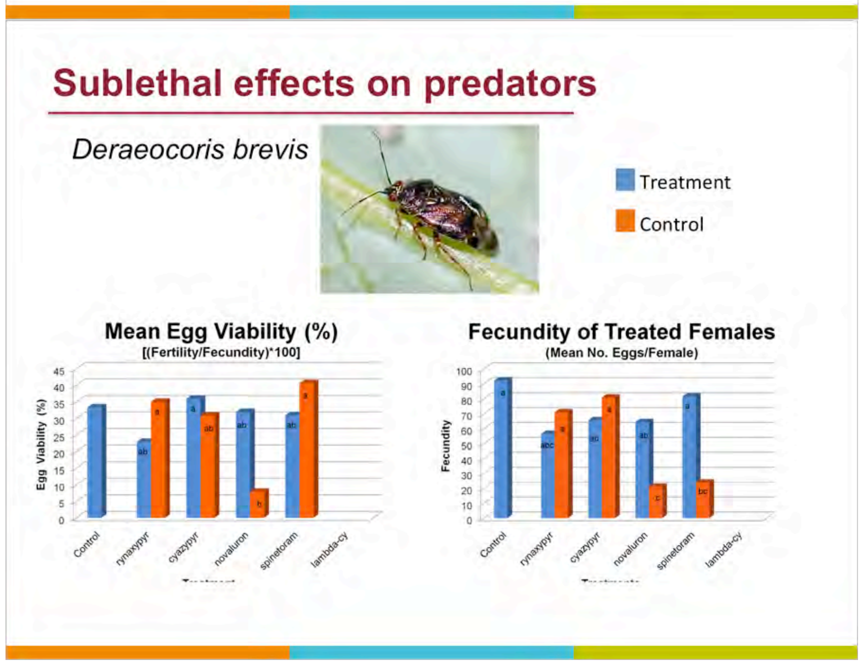
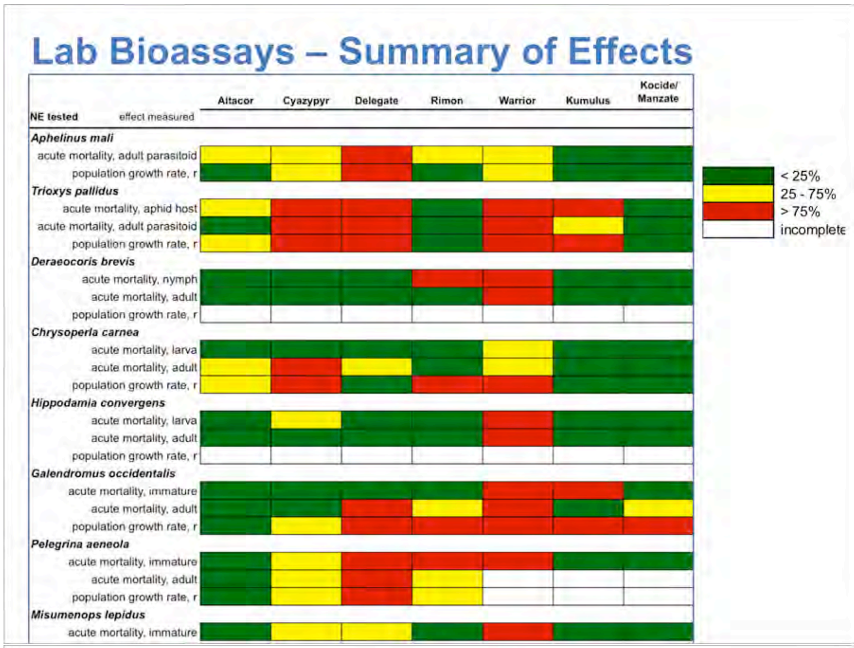




Notes:

Extrapolation with matrix models

Deraeocoris brevis

Pesticide	Pop growth rate
Control	0.255
Altacor	0.259
Cyazypyr	0.252
Delegate	0.150

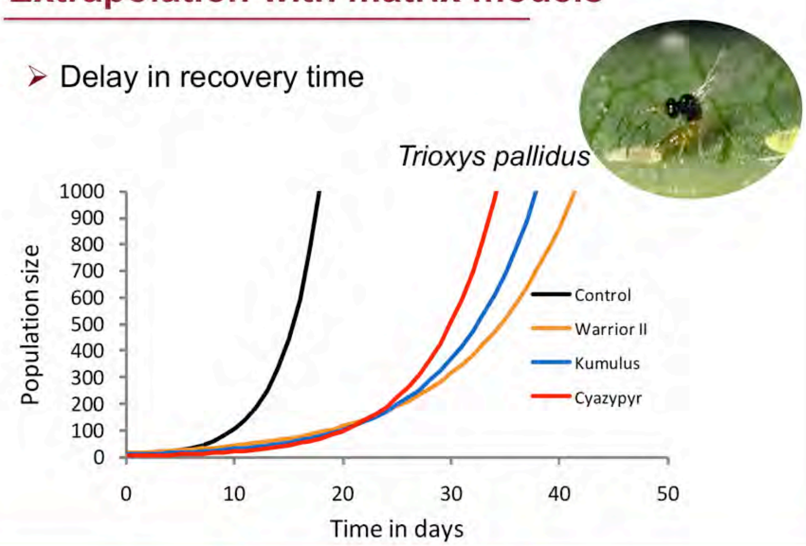
Galendromus occidentalis

Pesticide	Pop growth rate
Control	0.157
Altacor	0.142
Rimon	0.005
Delegate	-0.261

Notes:

Extrapolation with matrix models

- Delay in recovery time



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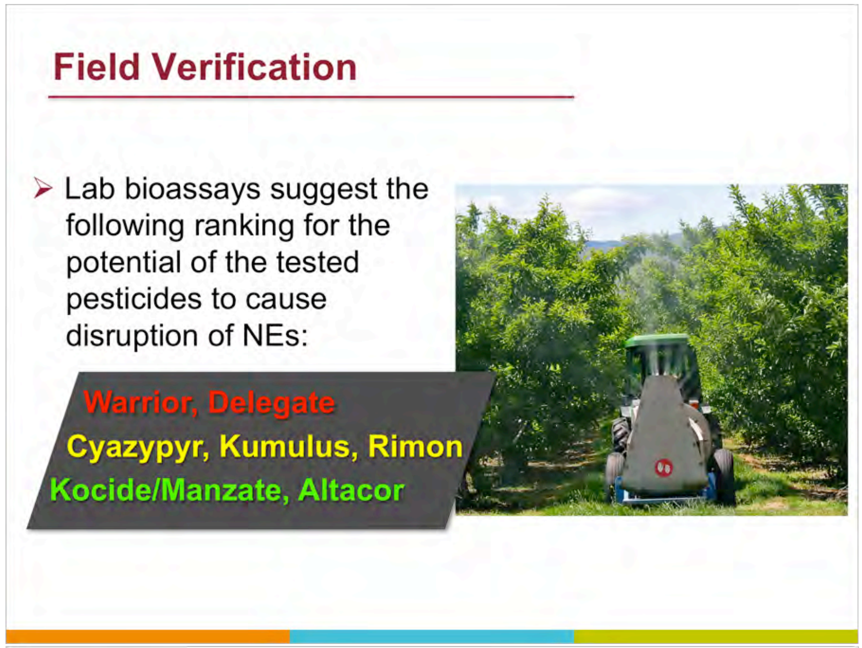

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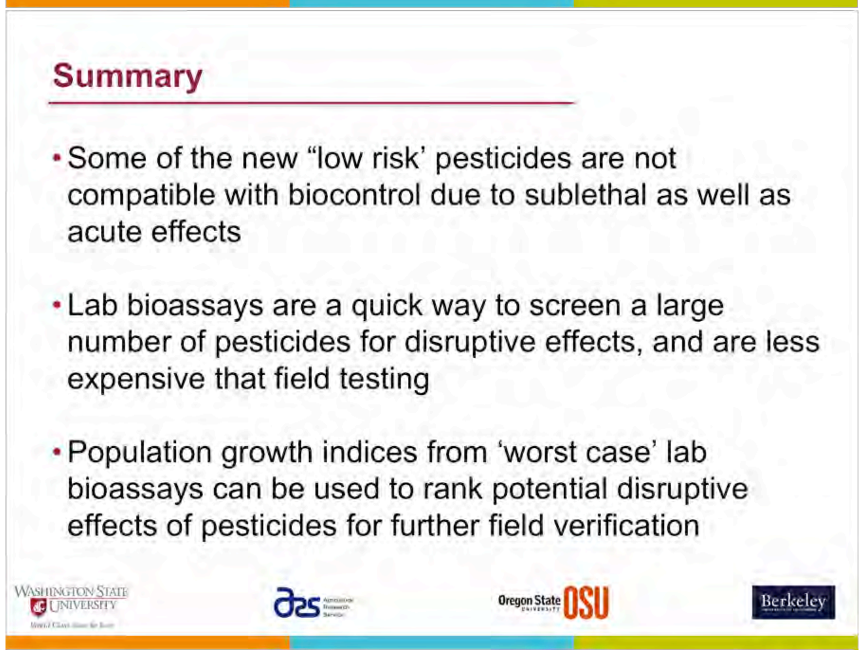

Next...

Case Study #1: Secondary Pest Problems - Why did they get out of control?

(Refer to materials starting on page 165)

End of Day 1 Presentations