

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 pest 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

General Overview and Introduction to Biological Control

Nick Mills, University of California, Berkeley

Vince Jones, Washington State University, Wenatchee

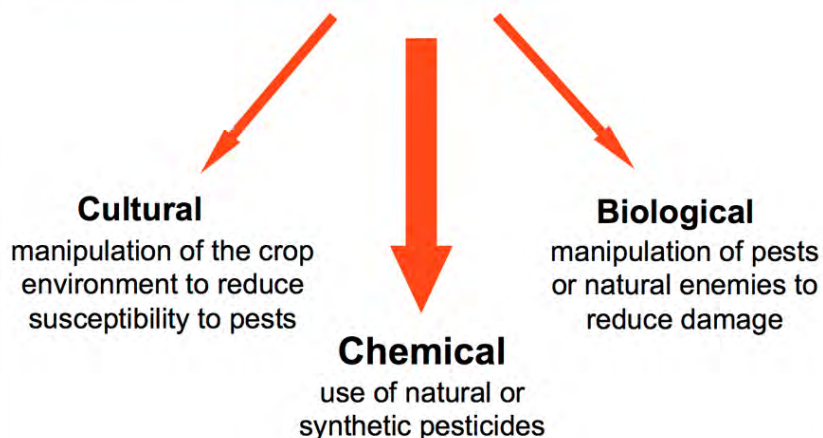


Overview

- 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



Notes:

Notes:

What is Biological Control?

The suppression of pest damage through the action of one or more living natural enemies



Notes:

What are Natural Enemies?

Pathogens



Parasitoids



Predators



Notes: *(Video on predators)*

Natural Enemies in Action: Predator



Courtesy of Prof. [Urs Wyss](#), Kiel University – Entofilms.com

Natural Enemies in Action: Parasitoid

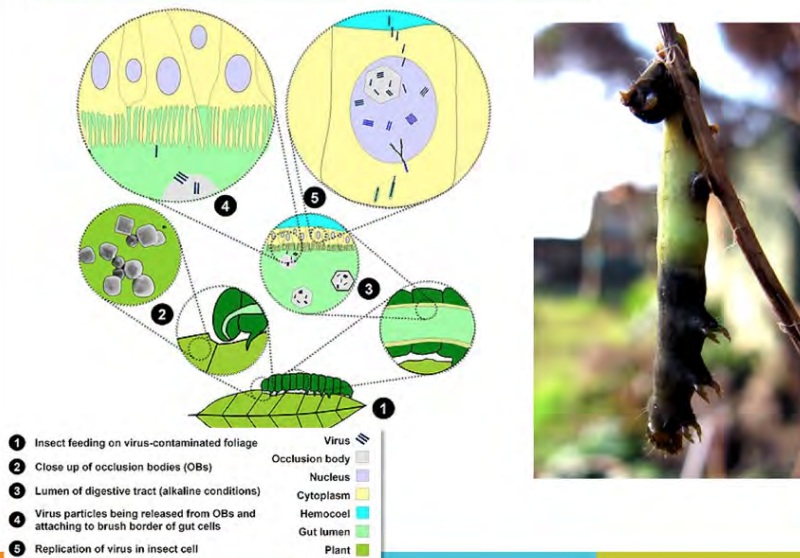


Courtesy of Prof. Urs Wyss, Kiel University – Entofilms.com

(Video on parasitoids)

Notes:

Natural Enemies in Action: Pathogen



Notes:

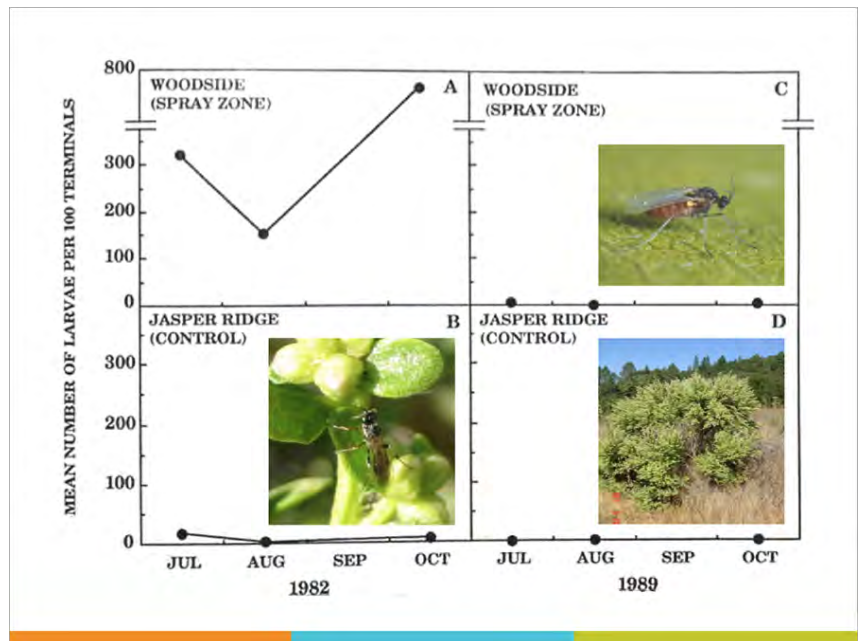
Naturally-Occurring Biological Control

- 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

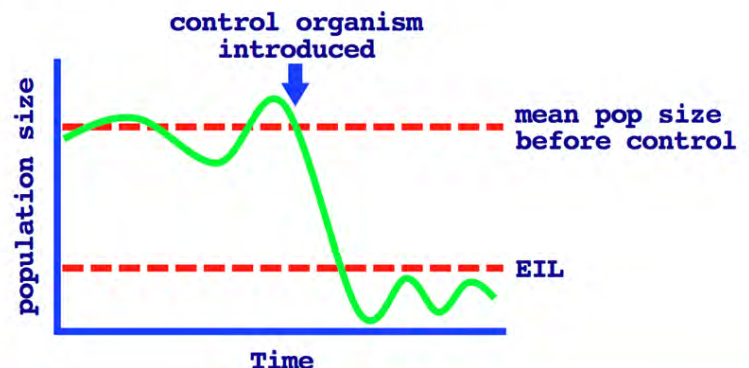
Conservation – enhance the activity of natural enemies through modification of the crop environment



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



Notes:

Importation Biological Control

- Used against invasive pests only

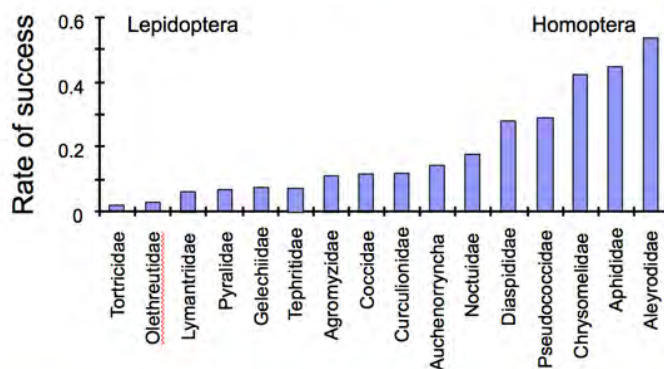


- A public good exercise supported by governments, not implementable by growers or industry
- Outcome, if successful, is long-term sustainable control

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:

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



Notes:

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

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

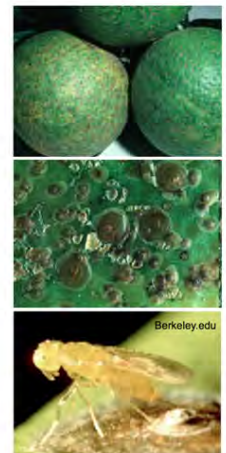
- Walnut aphid was a key pest of walnut production in CA in 1950s
- *Trioxys pallidus* was introduced from Iran in 1969
- Parasitism has provided sustained control of walnut aphid for > 40 yrs



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



Notes:

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 *Colpoclepeus 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 *Galenromus 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 *Galenromus*



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 to 12,700
- 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

Notes:

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

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Presentation 2: Principles of Pest/NE Interactions

Notes:

Principles of Pest/Natural Enemy Interactions

Vince Jones, Nick Mills, Andrea Bixby-Brosi

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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

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Notes:

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



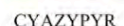
Why BC now?



Notes:

Registration of OP alternatives

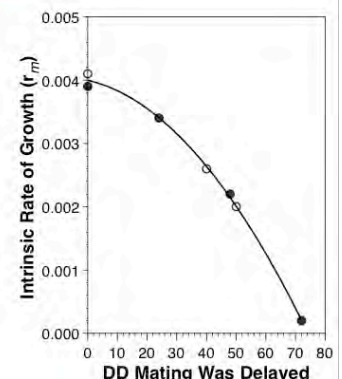
- Many different modes of action
- Resistance management for pests will disrupt NE developing resistance
- Effects on NE poorly known
 - Timing
 - Residual activity longer
 - Sub-lethal effects on reproduction/survival



Notes:

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

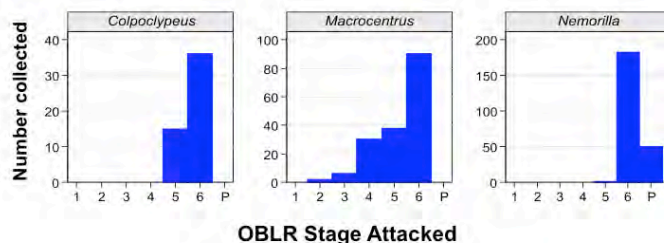
Basic information on NE/Pests

- 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



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:

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

Species	OBLR Stage	Number collected
Colpoclypeus	1	40
	2	40
	3	40
	4	15
	5	15
	6	35
	P	35
Macrocentrus	1	10
	2	10
	3	20
	4	30
	5	40
	6	90
	P	90
Nemorilla	1	200
	2	200
	3	200
	4	200
	5	180
	6	50
	P	50

OBLR Stage Attacked

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

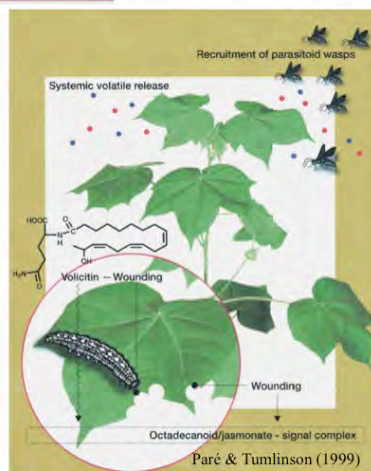


Specific Predators



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

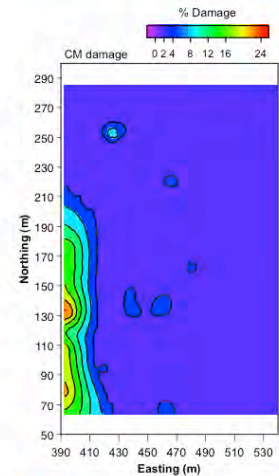


Notes:

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

Predator/Parasitoid Searching



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Notes:

Host-Associated Cues

Predator/Parasitoid Searching

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

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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



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Notes:

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?*

BC in conventional/organic

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:

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



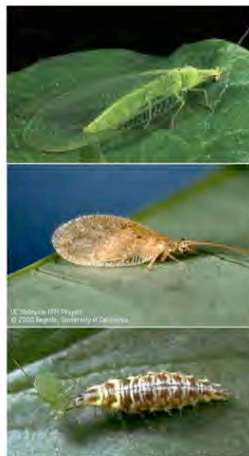
Key Natural Enemy Groups: Life Histories and Pests Controlled

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



Predators – Lacewing groups

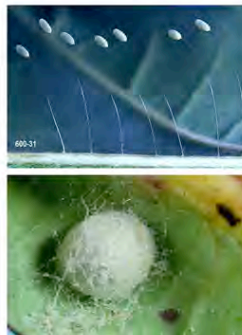
- Green lacewings (Chrysopidae) *Chrysoperla*
Chrysopa
- Brown lacewings (Hemerobiidae) *Hemerobius*



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

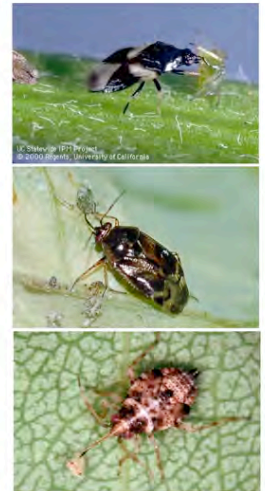
- Aphids
- Moth eggs/
young larvae
- Mealybugs
- Pear psylla
- Spider mites



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



Notes:

Predators – True bug prey

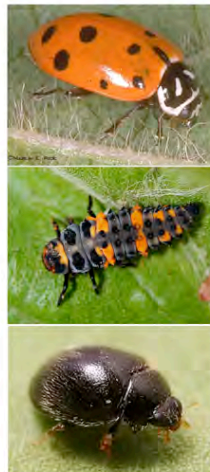
- Pear psylla
- Aphids
- Scale insects
- Spider mites



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:

Predators – Hoverflies (Syrphidae) and life history

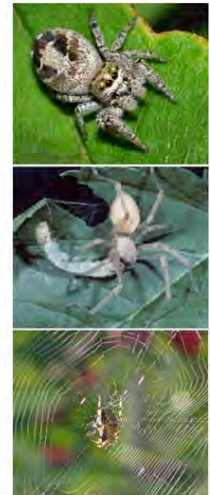
- Aphid feeders
Eupeodes, Scaeva, Syrphus
- Predatory as larvae only
- White eggs laid singly
- Rasping mouthparts
- Pupate within curled leaves
- Often parasitized as larvae and puparia



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



Notes:

Parasitoids of Moth Pests

- Ichneumonidae



- Braconidae



- Chalcidoidea



- Tachinidae



Notes:

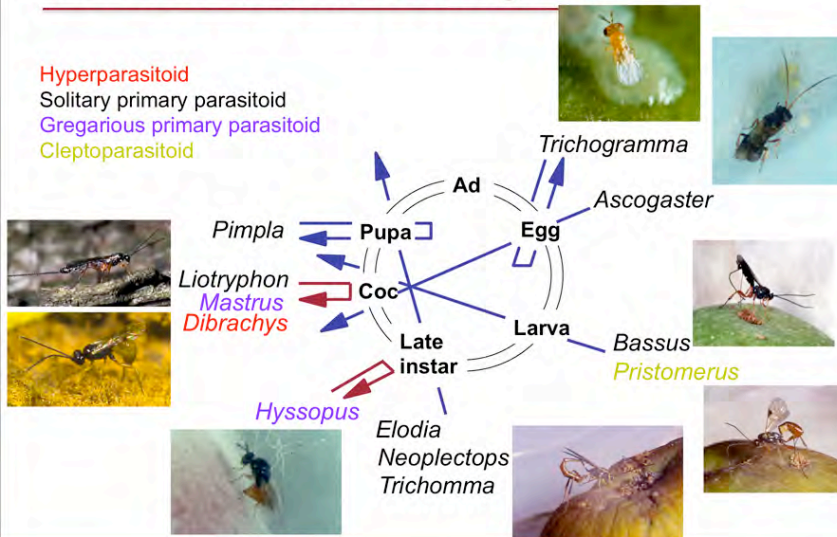
Parasitoid complex of codling moth

Hyperparasitoid

Solitary primary parasitoid

Gregarious primary parasitoid

Cleptoparasitoid



Notes:

Parasitoids of Aphids

- Braconidae (Aphidiinae)

Aphidius, *Ephedrus*,
Lysiphlebus, *Trioxys*



- Aphelinidae

Aphelinus



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

Notes:

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

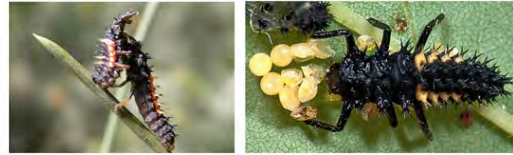


Notes:

Predator life styles

- *Cannibalism:*

feed on other individuals of the same species



- *Intraguild predation:*

feed on other species of natural enemy



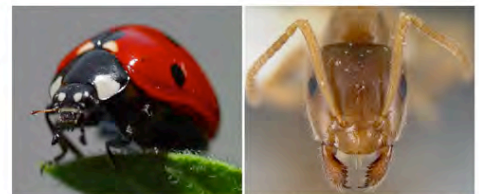
Notes:

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

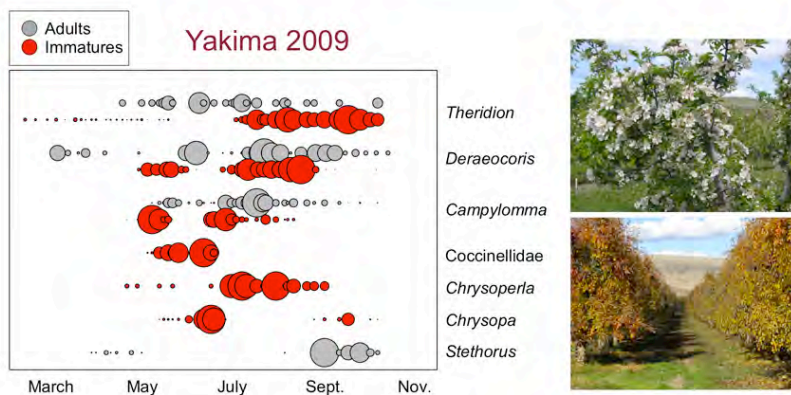
Notes:

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

Notes:

Summary

- Life history strategies of natural enemies can be complex and the seasonality and phenology of their activity (overwintering stage, timing and number of generations) are also highly diverse, which can complicate “management” of beneficials



Presentation 4: Exercise - Natural Enemy ID

Notes:

Natural enemy identification: Predaceous insects, parasitoids, and spiders

Gene Miliczky
USDA-ARS
Wapato, WA



Notes:

Natural enemies in orchards: Generalizations

- Natural enemy diversity in orchards is high: for example – parasitoids, ladybeetles, spiders
- Order and family level ID relatively easy – can usually be done in the field
- Species ID of adults and immatures can be challenging – magnification needed
- Adults and their immatures may differ markedly



Notes:

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:

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: $\sim 0.1'' - 0.2''$; 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

Notes:

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

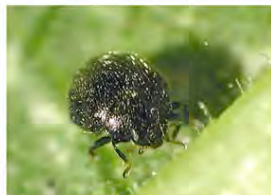
- Adults: delicate brown insects; rather weak flyers
- Larvae: elongate body; large, pointed mouthparts
- Eggs laid singly and are not stalked
- Prey: aphids, psylla, thrips



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:

Ladybird Beetles: Family Coccinellidae

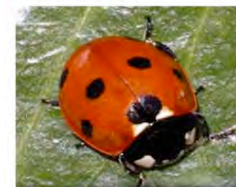
- Many species are brightly colored
- Color pattern: varies little in some species but is highly variable in others
- Hemispherical or oval in shape
- Many are general predators of soft-bodied prey
- Some specialize on mites, scale, mealybugs
- Many species occur in PNW orchards (18+)

Notes:

Some common LB's in PNW orchards



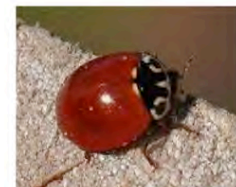
Convergent



7-spot



Halloween



Polished

Notes:

Two specialist LB's in PNW orchards



Stethorus
mite predator



Microweisea
scale predator

Notes:

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: 1/2"+



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:

Family Syrphidae: flower- or hoverflies

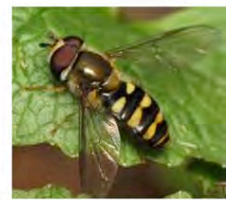
- Species of interest are aphid predators in the larval stage
- Larvae are typical maggots in appearance
- Adults of many species bear general resemblance to wasps or bees
- Adults feed on nectar and pollen and are of some benefit as pollinators

Notes:

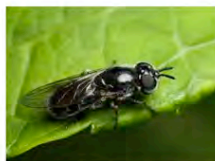
Common syrphids in PNW orchards



Scaeva



Eupeodes



Heringia

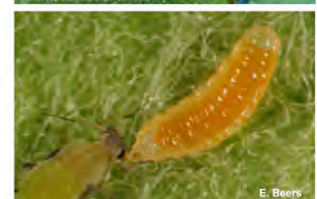


Syrphid larva

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



Notes:

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)



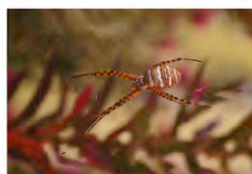
Lynx spider - *Oxyopes*



Philodromus cespitum



Sac spider w / PLR



Orb-weaver in her web

Notes:

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



Notes:

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:

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

Notes:

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:

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



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

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

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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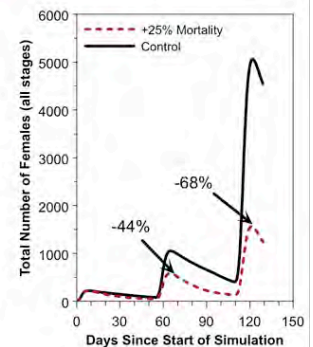
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Notes:

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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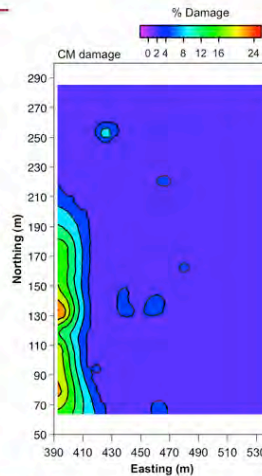
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Notes:

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

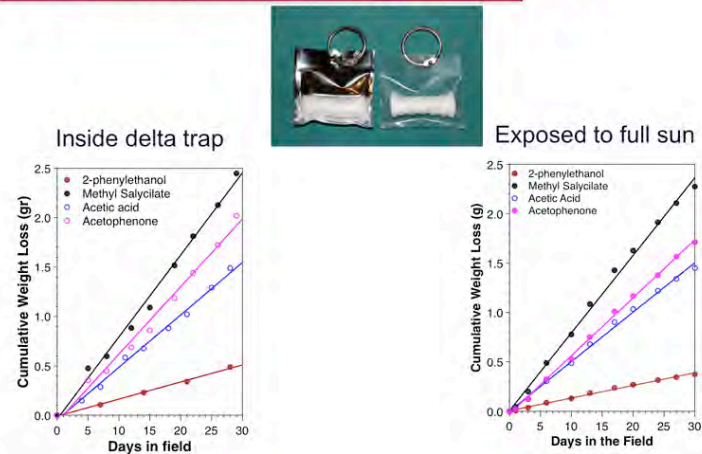


46 vs 153 days

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!

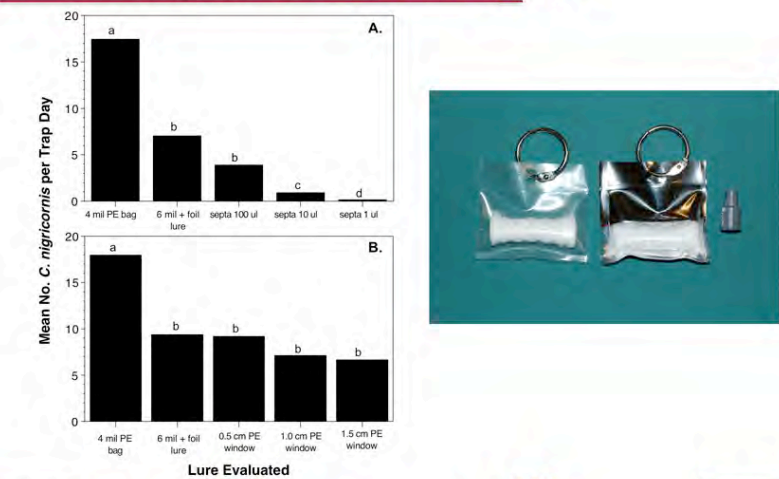
Notes:

SCRI accomplishments: *Release devices*



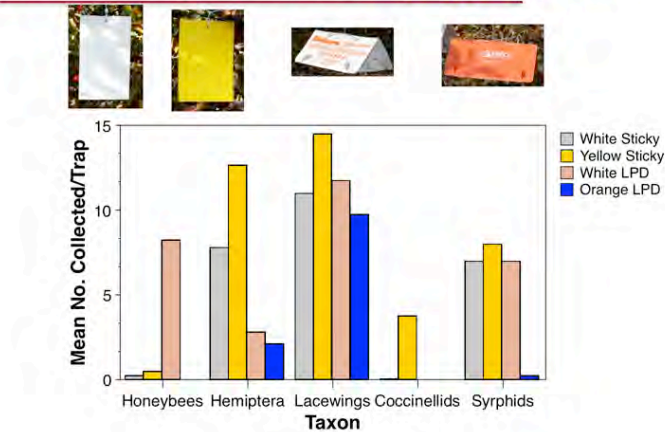
Notes:

SCRI accomplishments: *Dose-response*



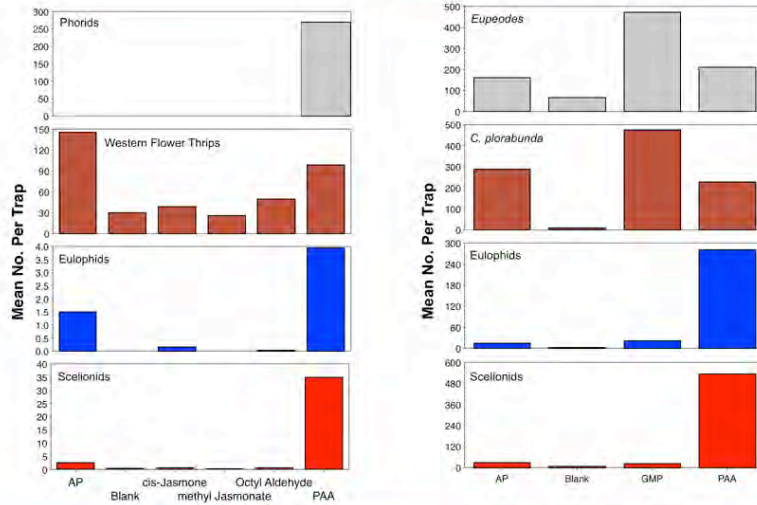
Notes:

SCRI accomplishments: *Trap-type effects*



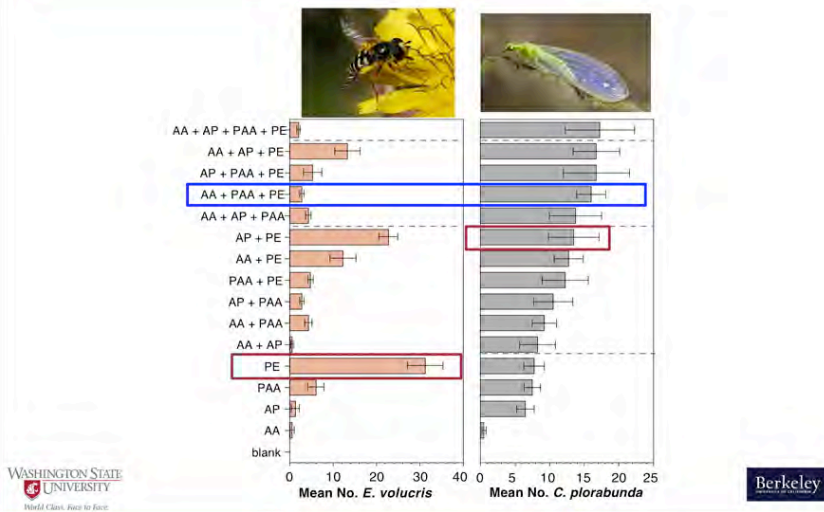
Notes:

SCRI accomplishments: *Attraction of different NE*



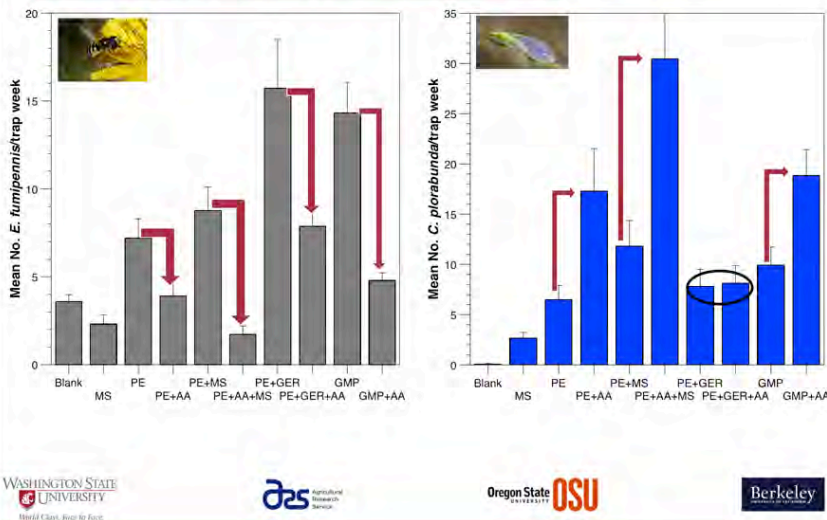
Notes:

Importance of Blends – Factorial Experiments



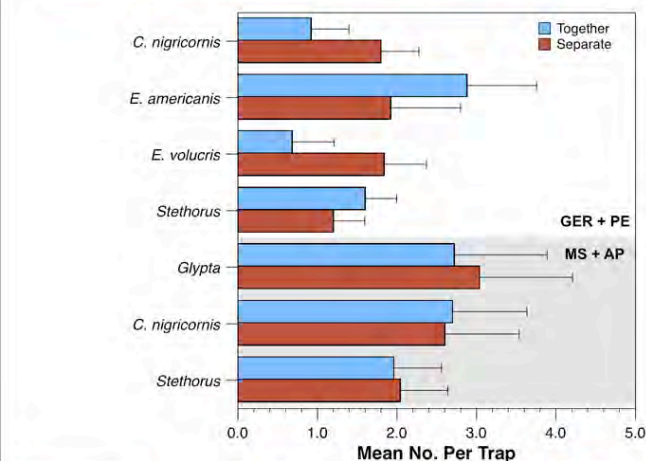
Notes:

Effect of AA – CA Walnuts 2011



Notes:

Mixing attractants – simpler lures



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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



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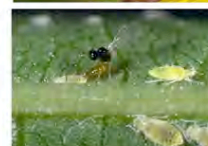
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Notes:

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



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Notes:

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



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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 \approx pest pheromones for IPM

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Presentation 6: NE Phenology, Modeling and IPM

Notes:

Natural Enemy Phenology, Modeling, and IPM

Vince Jones

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

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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?

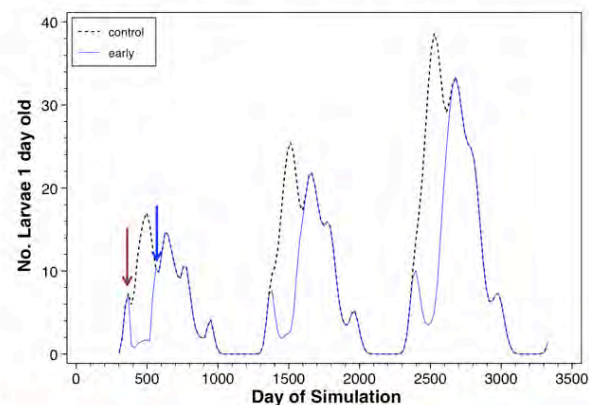
- NE reduce pest pressure & stabilize system
 - Eliminate NE, expect to pay for it!
- Minimize exposure of NE to pesticides
 - In Space
 - In Time
- Only certain stages are exposed to pesticides
 - “Windows of Opportunity”
- Sensitive times in NE life history
 - “Windows of Trouble”
- New models provide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



Notes:

Why are management programs unstable?

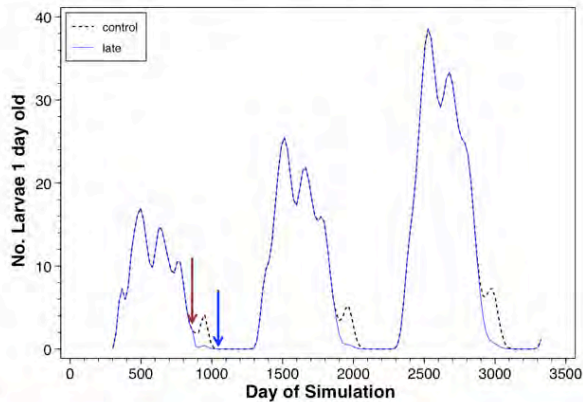
- Pesticides are applied at specific time for pest
- NE phenology unknown – effects are random



Notes:

Why are management programs unstable?

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



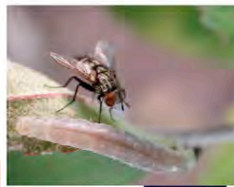
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Notes:

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!



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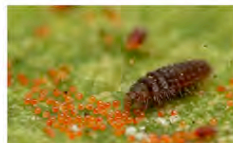
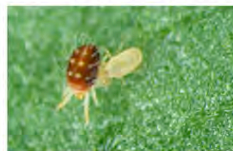
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Notes:

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



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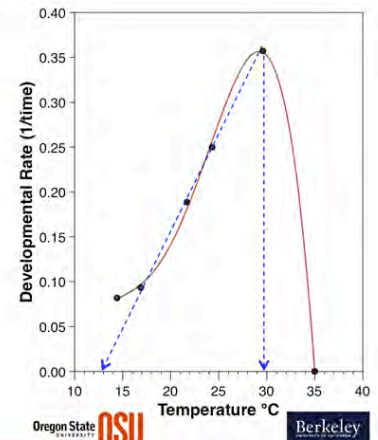
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Notes:

How models work

- Insect temperature \approx 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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Model Clinic: Run to Race

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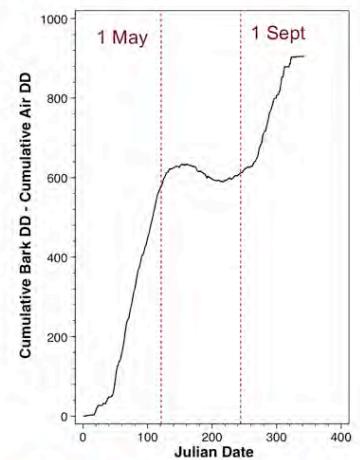
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Notes:

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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Model Clinic: Run to Race

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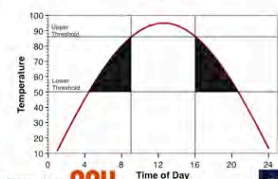
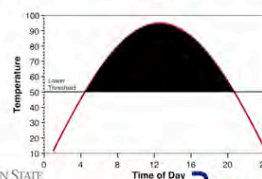
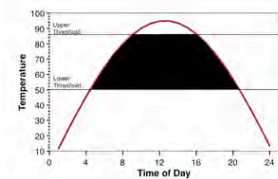
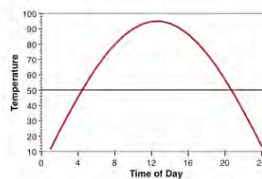
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Notes:

Calculating Heat Units (Degree-Days)

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



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Model Clinic: Run to Race

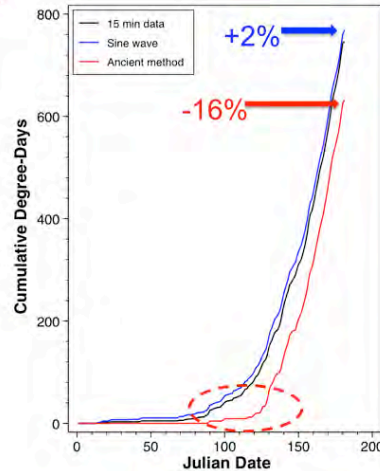
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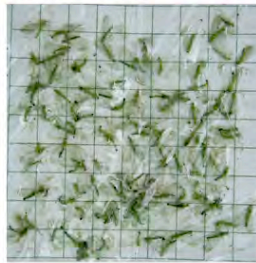
Accuracy of Methods

- 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



Field Validation

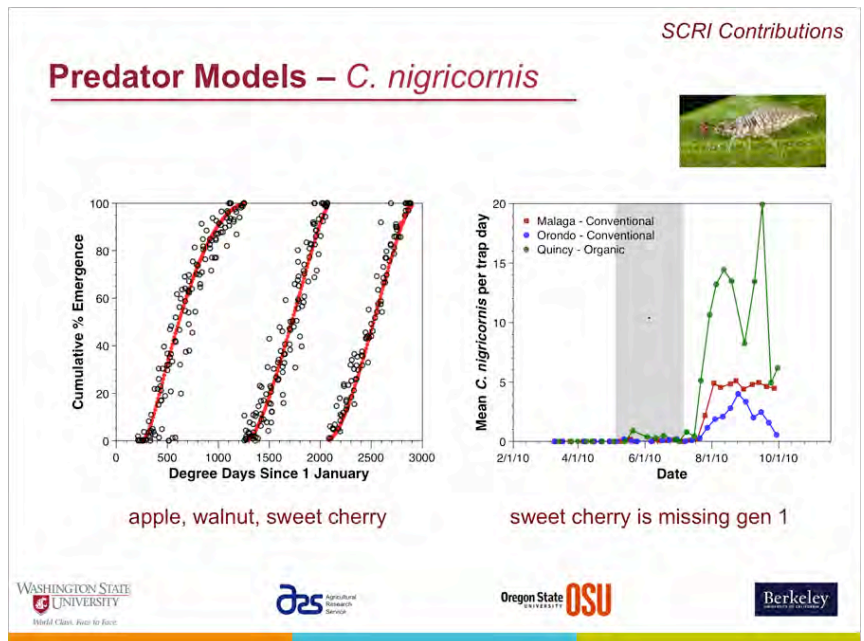
- Need multiple years, multiple sites
 - Variability in conditions and weather patterns
 - Need pests for NE presence
- Reliable sampling method
- Unsprayed or "lightly" treated orchards
- Pesticides change apparent phenology



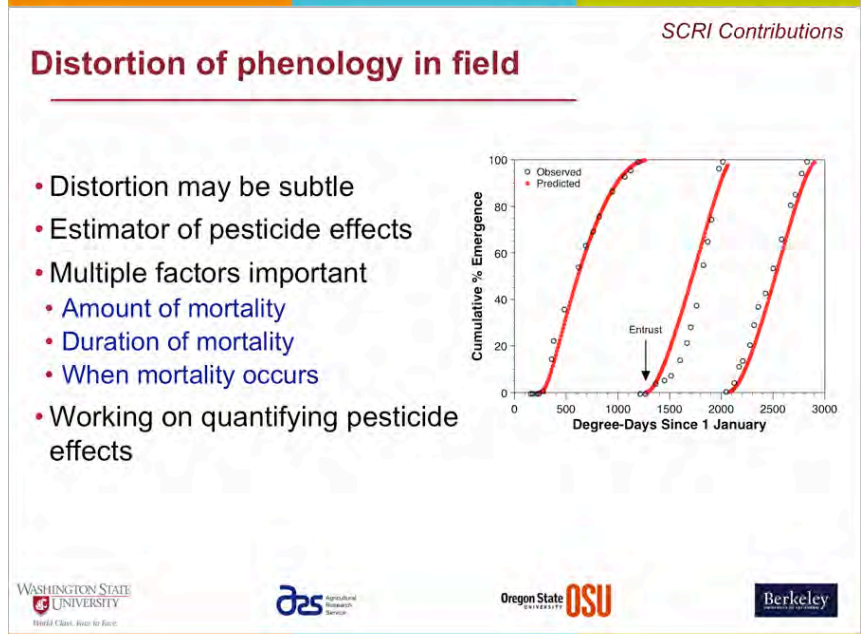
SCRI Project Work

- 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

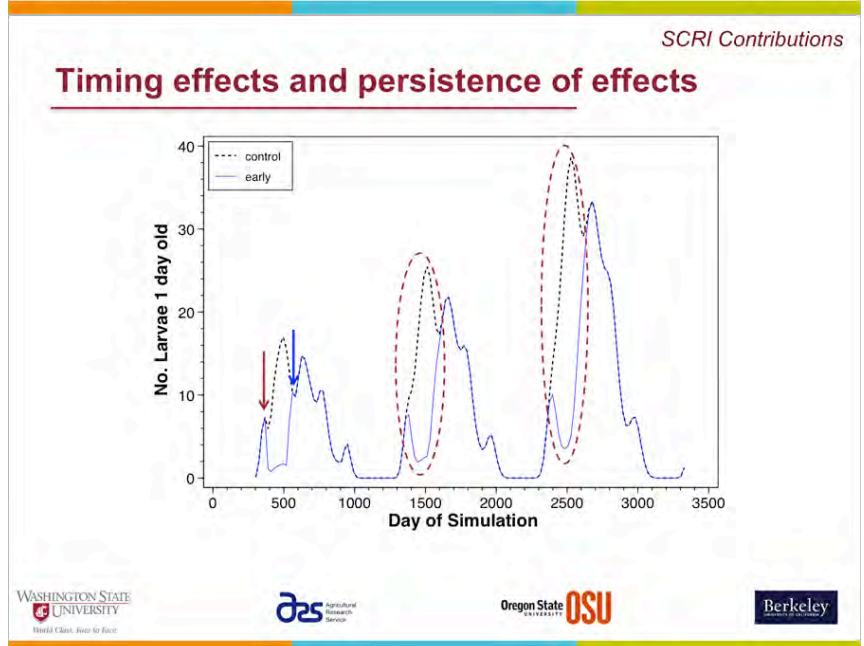
Notes:



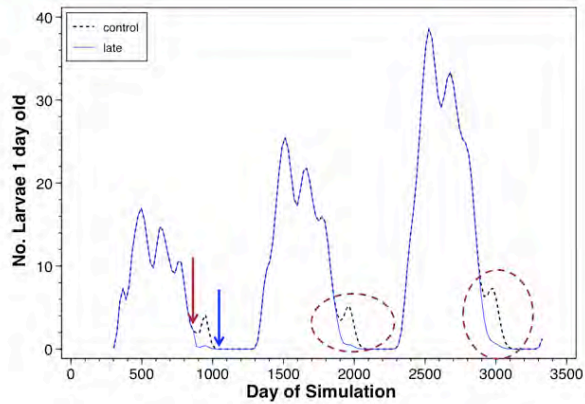
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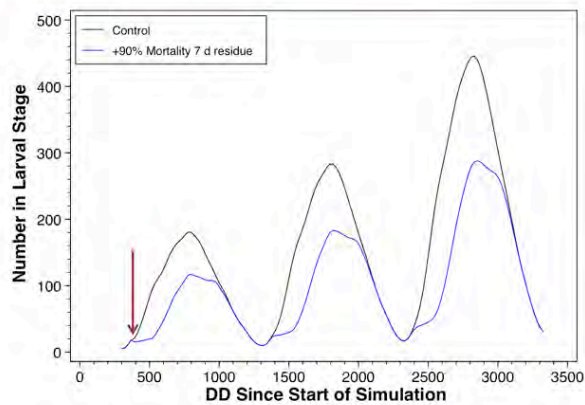
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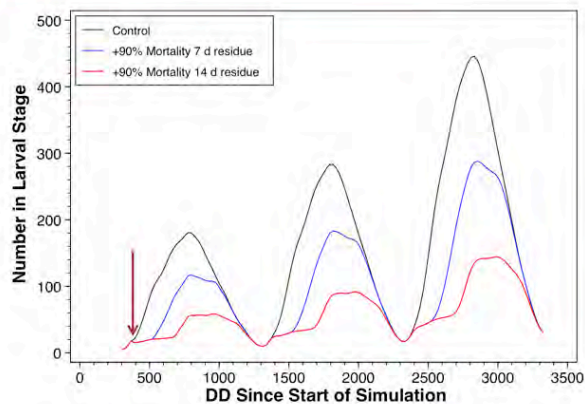
Timing effects and persistence of effects



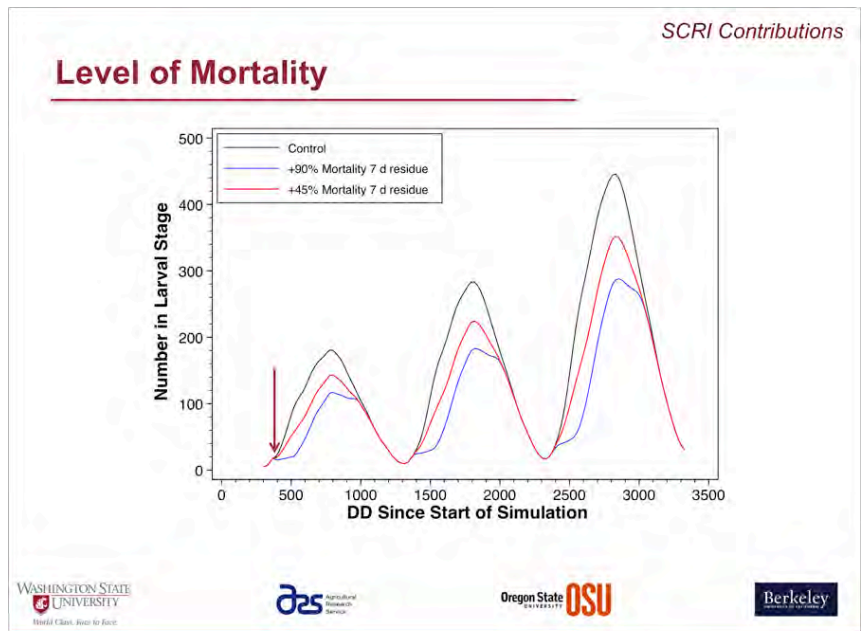
Longevity of Residue



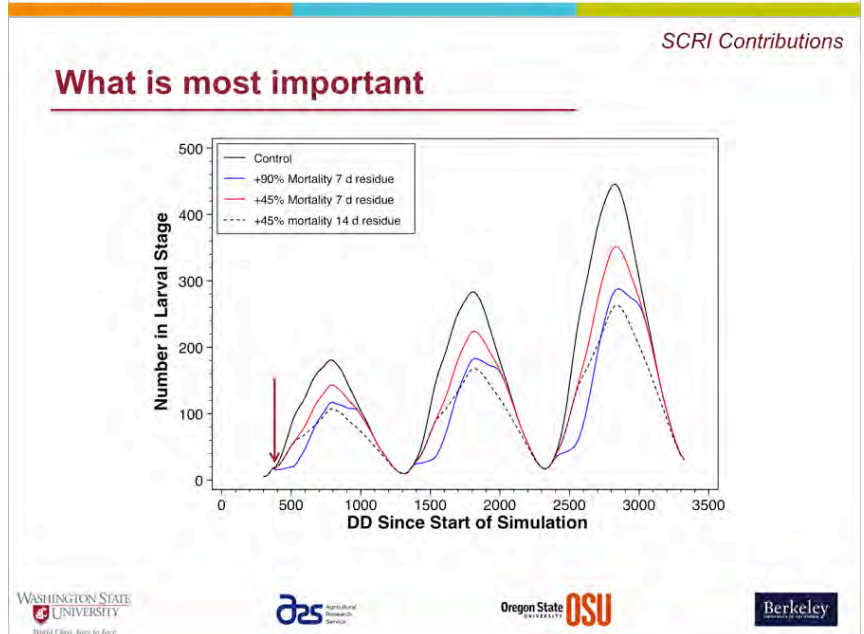
Longevity of Residues



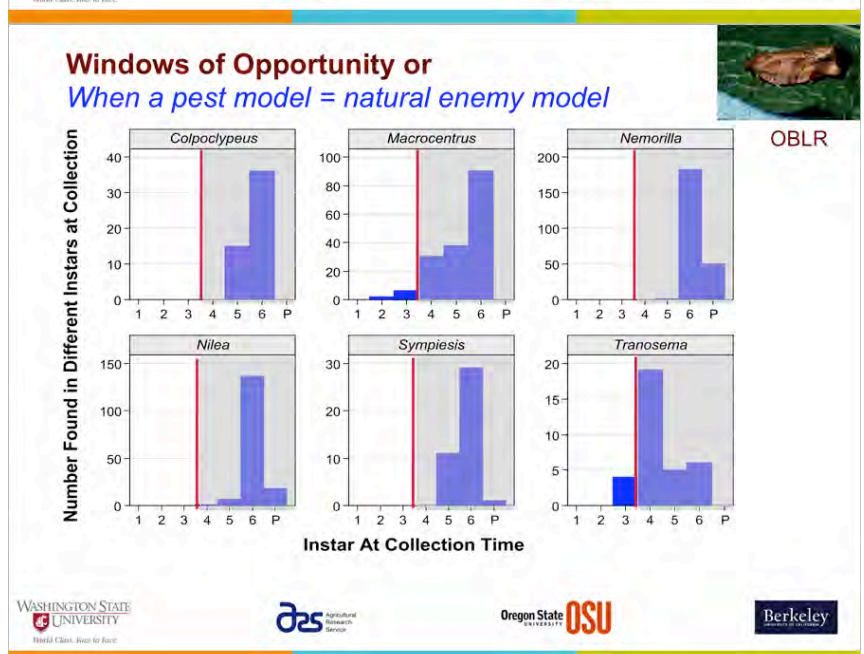
Notes:



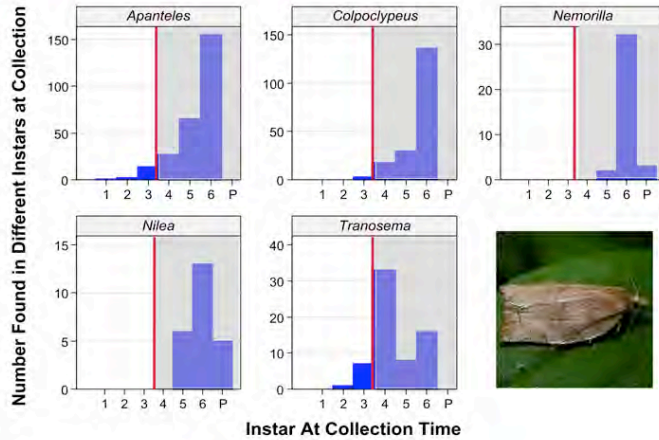
Notes:



Notes:



Windows of Opportunity



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?

Notes:

Getting the information to pest manager

das.wsu.edu

Decision Aid System

View By Model

Coding Moth

Projected Forecast

enhancedbiocontrol.org

Enhancing Western Orchard Biological Control

What's Inside

Follow us on

Participating Institutions

Notes:

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Summary

- Model NE for same reason as pest
- Instability in IPM happens because:
 - Pesticides applied for pests
 - Don't know:
 - When mortality happens in NE life cycle
 - Duration of effect
 - Level of mortality
 - Kill all the prey/hosts, starve the NE
- Windows of opportunity/disaster
 - Minimize NE exposure to pesticide residues
 - Harsher tactics possible inside window
 - Softer materials needed outside window
- Preserve NE saves money!



Presentation 7: BC Resources on the Web

Notes:

Biocontrol Resources on the Web

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

Notes:



Notes:

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Tree Fruit Research & Extension Center
Apple IPM Transition Project

November 30, November 2012

Full-time Assignment
Caitlin Thompson, Director
Lynne Page

TRFRC
TRFRC Entomology
Enhanced BioControl
Decision Aid System

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No-BioRx CM Model
Map of files
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Reference Tools

Assessment &
Documentation

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Search

Email us at:
ipm@trfrc.wsu.edu
ipm@trfrc.wsu.edu

Implementation Unit Handbooks

Overview

All participants of the Implementation Units are given a Handbook. The handbook covers various pest management topics of interest for apple growers. If you did not receive a handbook or are not a participant, you may download a copy of the Handbook below. The full copy of the Handbook will be a complete set of all pages from each section and will include any pages added/updated over the course of the season. The file size has been optimized to allow easy downloading. If you prefer, you can download each section separately (recommended if you have a slow connection).

Resumen

A todos los participantes de los Grupos de Implementación se les proveerá un manual. El manual resume varios temas para los productores de la manzana en cuanto al manejo de las plagas. Si usted no recibió un manual, o si no participa todavía, puede bajar una copia del manual en seguida. El manual completo contiene todas las páginas de cada sección y incluye las páginas agregadas/actualizadas durante la temporada. El tamaño de los archivos ha sido optimizado a aproximadamente 5MB para poder bajarlos fácilmente. Si prefiere, usted puede bajar cada sección individualmente (recomendado si usted tiene una conexión de internet lenta).

2010 edition release notes: The PMPH Manual underwent a major update. The new edition added new pages including an explanation of Degree Days, more pest monitoring, updating resources (including DAS 4.0), as well as changes to pages containing references to the Coding Moth model to reflect the no-biofix model. And, a Spanish edition of the Handbook is now available – see below.

[El manual en español está disponible!]

The manual of the PMPH was submitted to a new translation. The new edition includes various pages new, including a explanation of the Degree Days, more pest monitoring, updating resources (including DAS 4.0), as well as changes to pages containing references to the Coding Moth model to reflect the no-biofix model. And, a Spanish edition of the Handbook is now available – see below.

All files are in PDF format. - Todos los archivos están en formato PDF.

Click to download Adobe Reader  Haz clic aquí para descargar Adobe Reader

*Note: Some pages are left blank to better accommodate double-sided printing.
Neces: Algunas páginas están en blanco para dar cabida a una mejor impresión a doble cara.*

Complete 2010 Handbook	Manual Completo, 2010
Handbook files by section:	Archivos del manual por sección:
Section 1: Introduction	Sección 1: Introducción
Section 2: Mating Disruption	Sección 2: La Interrupción del Apareamiento
Section 3: Oribacteriophage (OP) Releases	Sección 3: Usando Reemplazos de OP
Section 4: Resistance Management	Sección 4: Manejo de Resistencia
Section 5: Monitoring	Sección 5: Monitoreo
Section 6: Secondary Pests	Sección 6: Plagas Secundarias
Section 7: Clean-up Programs	Sección 7: Programas de Limpieza
Section 8: Cultural Practices	Sección 8: Prácticas Culturales
Section 9: Web Resources	Sección 9: Recursos del Internet

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

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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
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Home & landscape
Agricultural pests
Natural environment
Exotic & invasive pests
Weed gallery
Natural enemies gallery
Weather, models & Pesticide information
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
Active stations only

stations in (Networks)
Networks
Map

station:
Enter all or part of a name.
List
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 Upper cutoff method (optional)

Single sine 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)
- Web-spinning Spider Mites (3/11)

Nematodes

- Nematodes (4/09)

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UC IPM Online
Statewide Integrated Pest Management Program

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Natural env

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
Assassin bug	Dermaptera family

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 leafroller parasite	Bracon cushmani
Citrus mealybug parasite	Leptomastix dactylopi
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
Hypoosoter exiguae, caterpillar parasite	Hypoosoter exiguae
Lysiphlebus testaceipes, aphid parasite	Lysiphlebus testaceipes
Tachinid flies	Tachinidae family
Trichogramma spp., egg parasites	Trichogramma spp.
Trioxys pallidus, walnut aphid parasite	Trioxys pallidus

Twicestabbed lady beetle	Chilocorus orbus
Vedalia beetle	Rodolia cardinalis
Western predatory mite	Galenromus occidentalis

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Crop Protection Guide

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All Any words

Go

Tree Fruit Research & Extension Center

Orchard Pest Management Online


edited by Elizabeth H. Beers & Jay F. Brunner

IPM concepts

Direct pests

Indirect pests

Beneficials



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Tree Fruit Research & Extension Center

Orchard Pest Management Online

OPM Online is based on the book "Orchard Pest Management: A Resource Book for the Pacific Northwest"

Edited by Elizabeth Beers, Jay F. Brunner, Michael J. Willett and Geraldine Warner
With original illustrations by Geraldine Warner
Published 1993 by the Good Fruit Grower, Yakima, WA

Concepts of Integrated Pest Management

Integrated Pest Management Overview

Insect Growth and Development

Animal Classification

Sampling

Biological control

Degree-day Models

Degree Day Tables

Insect Growth Regulators

Managing Pesticide Resistance

Mating Disruption

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Orchard Pest Management Online

Biological control

-- Tom R. Unruh
(originally published 1993)

Biological control is a means of keeping pests below damaging levels through the activities of predators and parasitoids. Successful biological control can occur with native natural enemies or may be due to the introduction of predators or parasitoids from foreign countries or different regions of the same country.

There are three major types of augmented biological control: classical, inoculative and inundative. These are distinguished by the input needed to create a balance between the pest and natural enemy populations.

Classical biological control involves introducing natural enemies from a pest's native range into a new area where native natural enemies do not provide control.

Inoculative biological control means releasing natural enemies periodically or seasonally to reestablish a balance that has not been maintained naturally or has been disrupted by other control methods.

Inundative biological control involves the massive production and release of natural enemies to control the pest quickly.

Pest populations may drop after a natural enemy is introduced. Unfortunately, biological control is seldom a predictive science. Biological control introductions are, in effect, grand ecological experiments.

For example, winter moth, a pest of oak, apple and several other deciduous trees, colonized Nova Scotia and British Columbia, Canada, where it became a pest. Dramatically successful control followed the introduction of two of the moth's natural enemies, a parasitic fly, *Cyzenis albicans*, and a parasitic wasp, *Agrypon flavellatum*. However, in England, part of the moth's native range, two decades of ecological studies indicated that those parasites did not control the moth. This discrepancy underscores the difficulty of predicting what factors are involved in successful natural biological control.

Effect of Natural Enemy



The figure shows how pest populations decline after the introduction of a natural enemy. It also shows how successful biological control – suppression of the pest below the economic injury level – depends on the type of pest. Direct pests, which attack the fruit, cause economic damage at much lower densities than indirect pests, which attack other parts of the tree such as foliage, roots, or woody tissues.

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Tree Fruit Research & Extension Center
Orchard Pest Management Online

OPM Online is based on the book "Orchard Pest Management: A Resource Book for the Pacific Northwest"

Edited by Elizabeth Beers, Jay F. Brunner, Michael J. Willett and Geraldine Warner
With original illustrations by Geraldine Warner
Published 1993 by the Good Fruit Grower, Yakima, WA

Natural Enemies and Beneficial Insects

Predatory Neuroptera Lacewings Snakeflies	Lady beetles Convergent lady beetle, transverse lady beetle, black lady beetle, Scymnus mealybug destroyer	Predatory flies Syrphid flies Cecidomyiid flies Leucopus spp.
Predatory bugs Deraeocoris Campylomma Anthrenorhynchus Other predatory bugs	Predatory mites Typhlodromus occidentalis Typhlodromus pyri Zetzellia mite	Predatory thrips Sixspotted thrips, black hunter thrips
Other predators Earwigs Ants Vespid wasps Spiders	Parasitic wasps Ichneumonids Ascogaster quadridentata Apanteles sp. Macrocentrus ancyloforus Phaenocarpa flavipes Colpoclypeus florus	Parasitic wasps (cont.) Aphelinus mali Tetraneura pyralis Trichogramma spp. Anagrus sp. Aphelopus typhlocyba
Parasitic flies Tachinids	Pollinator Honeybee	

Notes:

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Tree Fruit Research & Extension Center
Orchard Pest Management Online

Green lacewings
Chrysopa caesia (Stephens)
Chrysopa nigricornis (Burmester)
Chrysopa (Chrysopidae)

Brown lacewings
Leucospa flavipes (Gahan)
Leucospa nigrifrons (Gahan)
Leucospa nigrifrons (Gahan)
Leucospa nigrifrons (Gahan)

Life stages
Egg: The egg is oval, green or white and is suspended on a long, hair-like stalk. The egg is about 150 microns (0.15 mm) long, while the stalk is about 114 microns (0.11 mm) long. Eggs are laid singly or in groups.

Larvae: The larva's elongated body is yellow or mottled gray with red or brown and has a cluster of spines. Its prominent white mandibles, or jaws, are longer than the head and are used to capture and subdue the body parts. The larva develops through five instars and is about 20 mm (0.8 inch) long when mature.

Pupa: The larva pupates in an opaque, white or yellow, tightly woven, spherical cocoon. The pupa is green with many features visible externally.

Adult: The adult is a green or white, elongated insect with long, thin legs and long antennae. It is about 20 mm (0.8 inch) long.

Notes:

Cornell University
College of Agriculture and Life Sciences
Department of Entomology

SEARCH: GO

● Biocontrol ● GALS ● Cornell

BIOLOGICAL CONTROL A Guide to Natural Enemies in North America
Anthony Shelton, Ph.D., Professor of Entomology, Cornell University

Home | Overview | Types of Natural Enemies | Habitat of Natural Enemies Index | Resources

Parasitoids Pathogens Predators Weed Feeders

Are You A Student?

Welcome to this Cornell University World Wide Web site! This guide provides photographs and descriptions of biological control (or biocontrol) agents of insect, disease, and weed pests in North America. It is also a tutorial on the concept and practice of biological control and integrated pest management (IPM). Whether you are an educator, a commercial grower, a student, a researcher, a land manager, or an extension or regulatory agent, we hope you will find this information useful. The guide currently includes individual pages of approximately 100 natural enemies of pest species, and we envision continued expansion. On each of these pages you will see photographs, descriptions of the life cycles and habits, and other useful information about each natural enemy.

Four types of natural enemies are included in this guide. The images in the banner at the top of this page, with links, represent each of the types. Clicking on any of the buttons in the banner above, wherever it appears, will allow navigation to that section of the guide.

Researchers are encouraged to contribute their expertise to this website.
Credit will be given.

Photo Credits:
 Dan Olmstead (parasitoid wasp),
 Sandy Gahan (pathogen),
 Joe Opatowicz (predator wasp),
 R. Richard (weed feeder wasp)

BACK TO TOP

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Integrated Pest Management Resources

MICHIGAN STATE UNIVERSITY

Identifying natural enemies

Search

Search our IPM resources

Resources for managing pests

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

Related pest diagnostic/management programs

Diagnostic Services • SoilPlant 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, terps, 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 DiForzo, Michael Brewer and Takui 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 GROWN](#). Email the web developer.

Notes:

OSU Oregon State University

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

INTEGRATED PLANT PROTECTION CENTER

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 IPC 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](#)

Archives

[News](#)

[Temporary Links](#)

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Links

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IPPC Staff

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International Links

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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

IPMout NEWS

Employment Opportunities with IPPC

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.

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 predaceous 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.

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.

Lady Beetles

(Coleoptera: Coccinellidae)

Identification

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

Adalia bipunctata 1/2 - 3/4"

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

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.

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

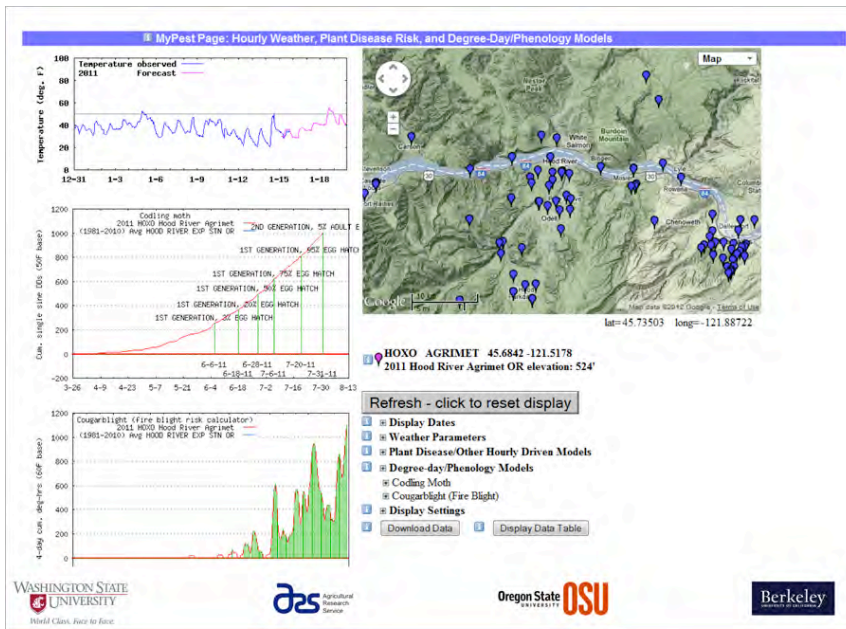
Brown lacewings, e.g., *Hemerobius apt*

Observation tips

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

Predacious activity

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



Notes:

2011 Pacific Northwest Insect Management Handbook

Chapter: Tree Fruit Section: Pear

<http://pnwpest.org/pnw/insects>

Pear—Pear psylla

(*Cacopsylla pyricola*) ID photos: [A](#) [B](#) [C](#) [D](#) [E](#) [F](#) [G](#) [H](#) [I](#) [J](#) [K](#) [L](#) [M](#) [N](#) [O](#) [P](#) [Q](#) [R](#) [S](#) [T](#) [U](#) [V](#) [W](#) [X](#) [Y](#) [Z](#) [AA](#) [AB](#) [AC](#) [AD](#) [AE](#) [AF](#) [AG](#) [AH](#) [AI](#) [AJ](#) [AK](#) [AL](#) [AM](#) [AN](#) [AO](#) [AP](#) [AQ](#)

[fact page \(pdf\)](#) [ID](#)

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 overwinters 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 predaceous 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 50°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

Growing-season spray
1. azadirachtin (neem extract)—if control is not satisfactory, add minimal rates of superior oil. Products containing neem extract may be phytotoxic to some pear cultivars.

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Notes:

2011 Pacific Northwest Insect Management Handbook

Chapter: Tree Fruit Section: Pear

<http://pnwpest.org/pnw/insects>

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, parasitoids (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:

- Classical biological control
- Augmentative biological control
- 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 ribwort 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 ribwort aphid below treatment thresholds. In another case, the spread of and damage by the apple lemine moth, (*Yponomeuta malinellus*), has been greatly reduced by the successful introduction of a wasp parasite, (*Apanteles fuscicornis*) in the late 1990s. An egg-larval parasitoid, (*Microplitis croceipes*) (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 biotopes.

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 control since 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 agriculture 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-disturbed 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

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Decision Aid System
Better IPM through science and technology.

Video Help

News / Updates

Page 14 of 19 | Displaying articles 66 - 70 of 93

AZM (Guthion) Phase-Out

Published on Friday, April 26, 2010 10:44 AM

The EPA phase-out of AZM (azinphos-methyl, Guthion) is in its third year, which means growers are only allowed 2 pounds of active ingredient per acre in apple. This limit in active ingredient means that growers will be restricted to two effective applications in 2010. Next year (2011) only 1.5 pounds of active ingredient is allowed, which means only one application of a high labeled rate. So, if you have been putting off the inevitable it is time to adopt OP-alternative insecticides into your pest control program.

San Jose Scale Management

Published on Thursday, April 29, 2010 10:45:03 AM

San Jose scale is a relatively easy pest to control, but a dangerous one to leave uncontrolled. After a few years of infestation, limbs and even entire trees can be killed if heavily attacked, and high percentages of the fruit can be infested. Large trees are most often associated with scale problems, because of the suitable habitat they provide and the difficulty of obtaining thorough spray coverage. However, young trees can also develop a scale problem surprisingly quickly.

Preserving Biocontrol Agents

Published on Thursday, April 29, 2010 04:29:43 AM

Natural enemies (NE) are crucial to the long-term stability of management programs. Pesticides need to be chosen not only on the basis of efficacy against the pests, but also by minimizing their effect on natural enemies. DAS provides both the effects on pests and on the key natural enemies.

New CM Control Strategies

Published on Wednesday, April 28, 2010 04:26:37 PM

A new method of controlling codling moth has been developed at WSU where timing of the sprays is altered to take advantage of the slow start of egg laying.

Monitoring Adult Codling Moth

Published on Thursday, April 15, 2010 03:08:52 PM

Adult codling moth (CM) are monitored with traps baited with either CM pheromones or a mixture of pheromones and an attractant (Combo D/A lure). Pheromone traps should be placed in the upper 1/3 of the tree canopy before first apple blossoms.

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Other WSU News

Agricultural WSU Today WSU Highlights

- Onion Pathogen, Wheat Flour, Takin...
- Learn to Grow Mushroom at Nov. 19 ...
- October Warmth Gives Growers Breat...
- CAHRS News - November 4, 2011
- WSU Launches Publication Focused o...
- UI, WSU Team Up to Present Film ab...
- Boxing Launches WSU Efforts in Sto...
- Stepping Up to a Bright Idea
- MEDIA ALERT: Press Invited to Cher...
- Got Good Hay?

Notes:

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Decision Aid System
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Home

Preserving Biocontrol Agents

Posted on Thursday Apr 29, 2010 4:28am

Natural enemies (NE) are crucial to the long-term stability of management programs. Pesticides need to be chosen not only on the basis of efficacy against the pests, but also by minimizing their effect on natural enemies. DAS provides both the effects on pests and on the key natural enemies.

The full **WSU Sprayguide** (accessible through the link "View full WSU Sprayguide" in the Mini Sprayguide in the model output) provides help with choosing pesticides. The efficacy of each material to control the target pest as well as secondary pests (e.g. Bees)

"Efficacy." The category "Natural Enemies" indicates how much each pesticide negatively impacts the listed natural enemies. This list includes predatory mites (*Typhlodromus occidentalis*), a parasitic wasp that attacks leafrollers (*Colpoclypeus florus*), a parasitic wasp that attacks leafminers (*Prigalia flavipes*), and aphid predators (ladybugs and lacewings). Apple rust mites, also listed, serve as food source for the predatory mite *T. occidentalis* early in the season and, thus, help to raise predator numbers that control spider mites later in the season. In particular, granulosis virus, oil, and Bt have low to no negative impact on natural enemies. To get more help on how to use the WSU Sprayguide, watch this video tutorial in the DAS Help Center.

Among the **natural enemies of leafrollers** are parasitic wasps, parasitic flies, predatory beetles, and birds. Oblate-banded leafrollers (**OBLR**) are predominantly parasitized by tachinid flies (*Nemorilla* and *Nilea*), both of which have their greatest impact late in the summer and which occur in virtually all orchards. Parasitic wasps also play an important role in biological control of OBLR. Pandemis leafrollers (**PLR**) are parasitized by wasps as well as tachinid flies. By changing your spray programs to target the young larvae of both species (which start the damage) biological control of the later instars is preserved (parasitoids don't attack young larvae) and fewer insecticides will be required.

Enhancing Western Orchard Biological Control is a joint project of WSU, OSU, USDA-ARS.

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Notes:

Home **View Models** My Profile Historic Data Import Data Help Center

View By Model

Models

- Apple Maggot
- Apple Scab
- Campylomyia
- Cherry Mildew
- Cherry Shothole
- Codling Moth
- Fire blight
- Lacinobla
- Oblate-banded Leafroller**
- Oriental Fruit Moth
- Pandemis Leafroller
- Peach Twig Borer
- San Jose Scale
- Storage Scald
- Sunburn Browning of Apples
- Western Cherry Fruit Fly

View all Stations with the Oblate-banded Leafroller Model

Mattawa Station

Weather Forecast **View Conventional**

Oblate-banded Leafroller

Last Updated: 07/22/2011
Degree days since January 1st. = 1176

Current Conditions:
28% of the summer generation is in 4th-6th instar, the rest are younger.

Management:
Treatments for the summer generation should be on by 1240 DD for greatest efficacy and to protect the natural enemies which attack the 5th and 6th instars. This is also the time to sample for summer generation larvae for estimation of population densities to determine efficacy of past treatments and need for treating new overwintering generation.

Projected Forecast:
+10 days Mon Aug 1, 2011 : 1364

Conditions:
86% of the summer generation is in 4th-6th instar, and 8% are in the pupal stage. The first 1% of the summer generation adult flight should occur at roughly 1365 DD and increase up to about 1800 DD.

Management:
The time when pesticides should be applied is over for the summer generation for maximum efficacy and to protect the natural enemies which are most abundant at this time.

WSU Mini Spray guide
Possible **Organic** materials for **Apple** crops.
Crop Type: **apple**
Crop Stage: **Late spring and summer**
Bacillus Thuringiensis Subsp. Kurstaki (Dipel DF)
Spinosad (Entrust 80W)
[View Full WSU Spray guide](#)

Graph of Relative Number in each Stage

Instar	OBLR	OBLR + 10 Days
1st	15	0
2nd	25	0
3rd	35	0
4th	10	15
5th	5	10
6th	2	5
Pupae	0	2

WSU Spray Guide Recommendations

Coding 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:

	chlorantraniliprole	petroleum oil-summer	spinosad
Altacor 35WDG			Entrust 80W microorganism
28			5
IV		III	III
4 h		4 h	4 h
5 d		0 d	7 d
3-4.5 oz		1 % v/v	3 oz
conventional		organic	organic
Not rated			WTL, OBLR, PLR
Not rated	ARM, ERM, TSM, GAA, WAA, WAL, CM	WTL, OBLR, CM, PLR, WFT, LAC	

	chlorantraniliprole	petroleum oil-summer	spinosad
<i>Typhlodromus occidentalis</i>	none	M	
Apple Rust Mite	none	?	?
<i>Colpoclypeus florus</i>	none	IT	IT
<i>Prigalio flavipes</i>	none	IT	IT
Coccinellids	none	IT	IT
Lacewings	none	IT	IT

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 these materials should

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Notes:

Presentation 8: Exercise - Windows of Opportunity

Notes:

Windows of Opportunity

Short Exercise



Notes:

Leafroller parasitoids

- Attack 4th-6th instar and/or pupae



Notes:

OBLR & PLR

Obliquebanded leafroller



Photo: WSU Extension



Photo: WSU Extension

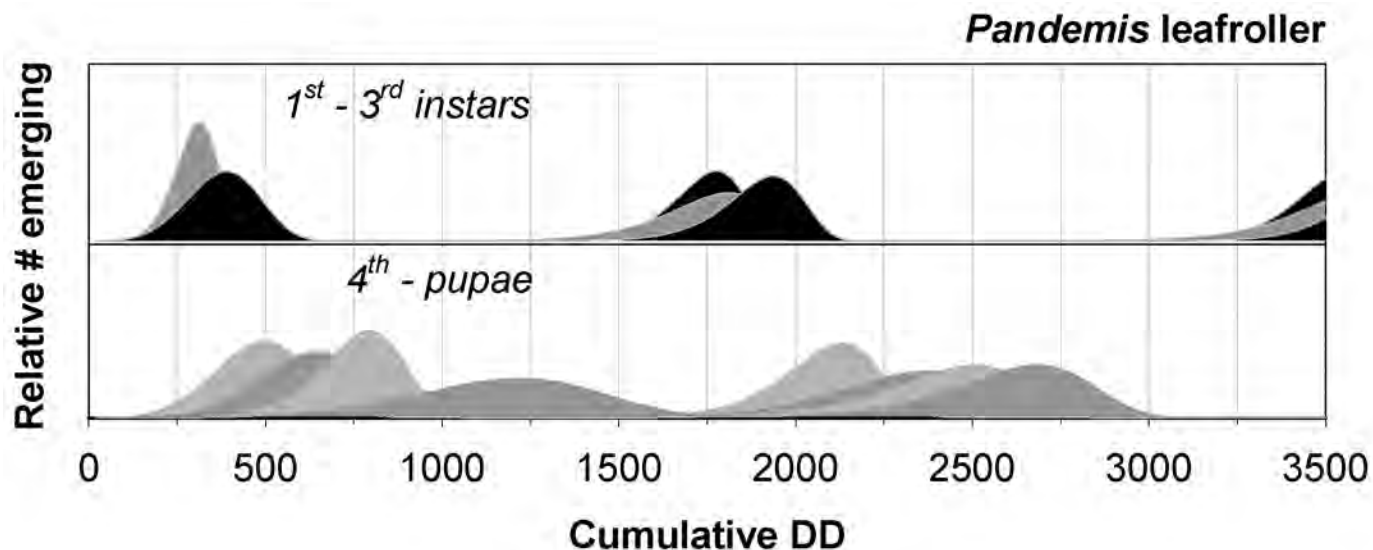
Pandemis leafroller



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

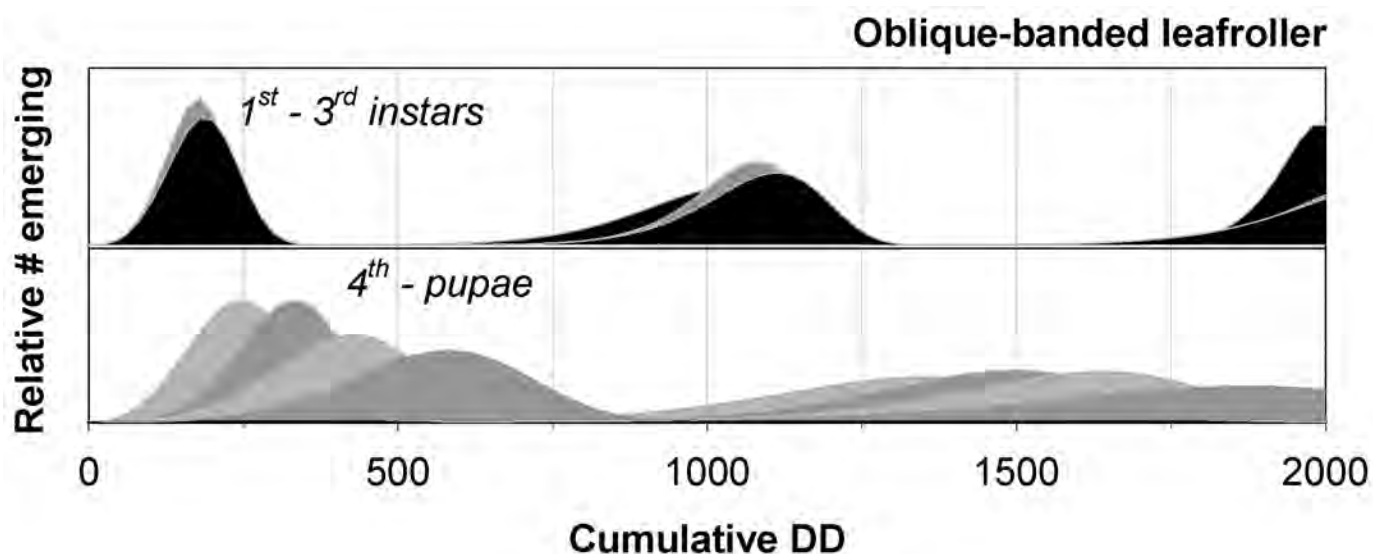
Task 1a: On the chart below, mark when parasitoids are present and when you should avoid sprays; then mark when sprays can be applied without harming PLR parasitoids.

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.

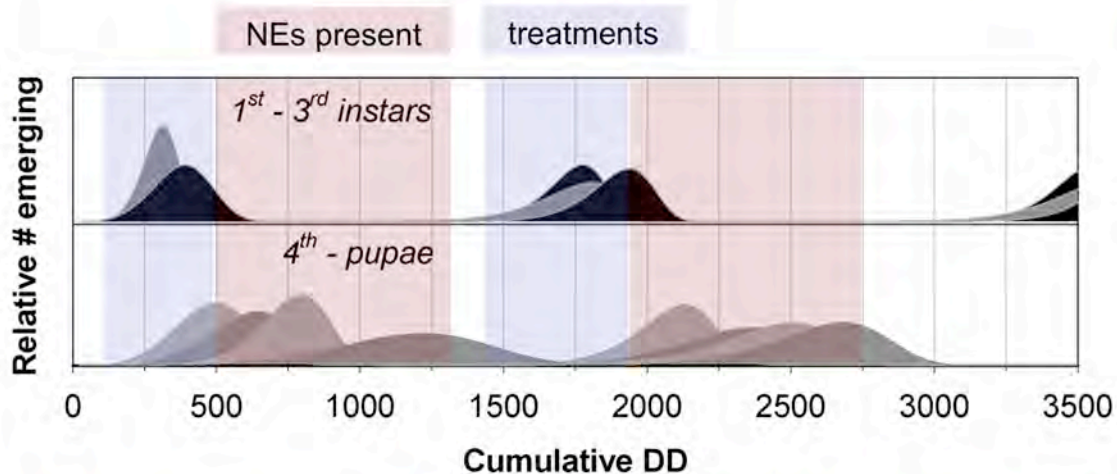
OBLR Phenology



Windows of Opportunity for PLR



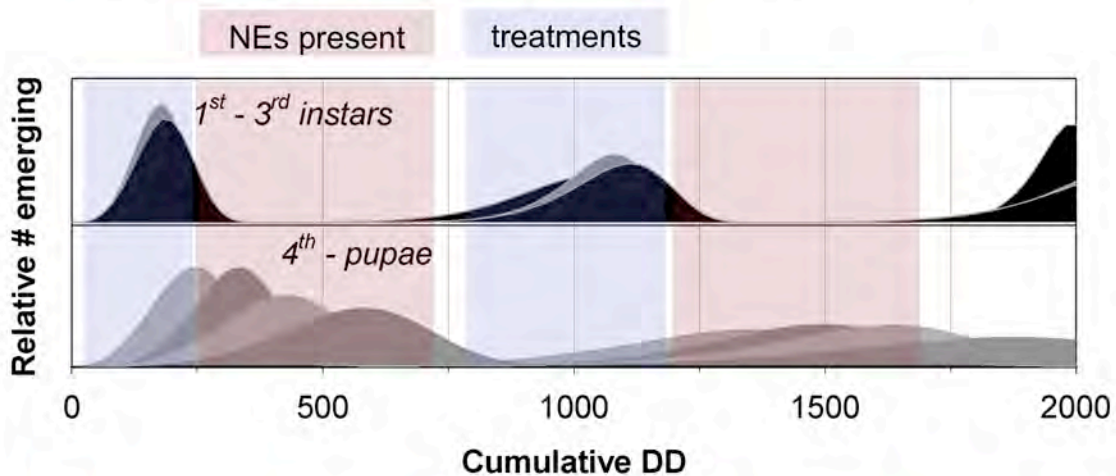
- 29% mortality in overwintering gen., 45% in summer gen.



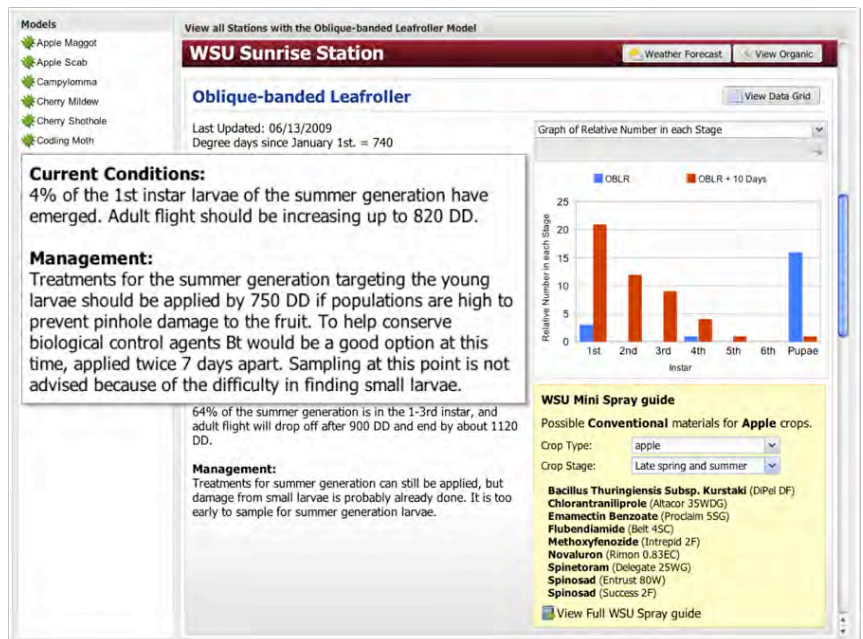
Windows of Opportunity for OBLR



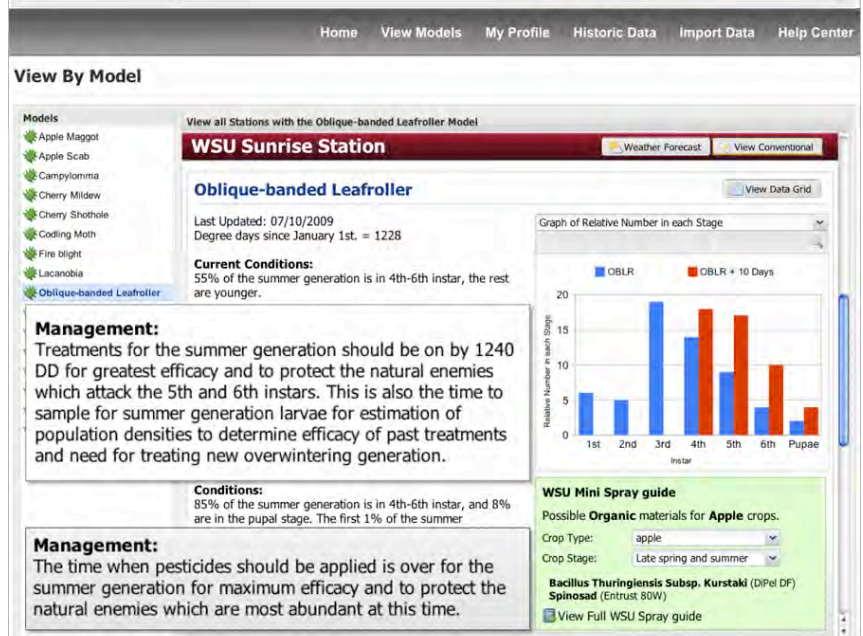
- 19% mortality in overwintering gen., 29% in summer gen.



Notes:



Notes:



Notes:

When and how to monitor leafrollers

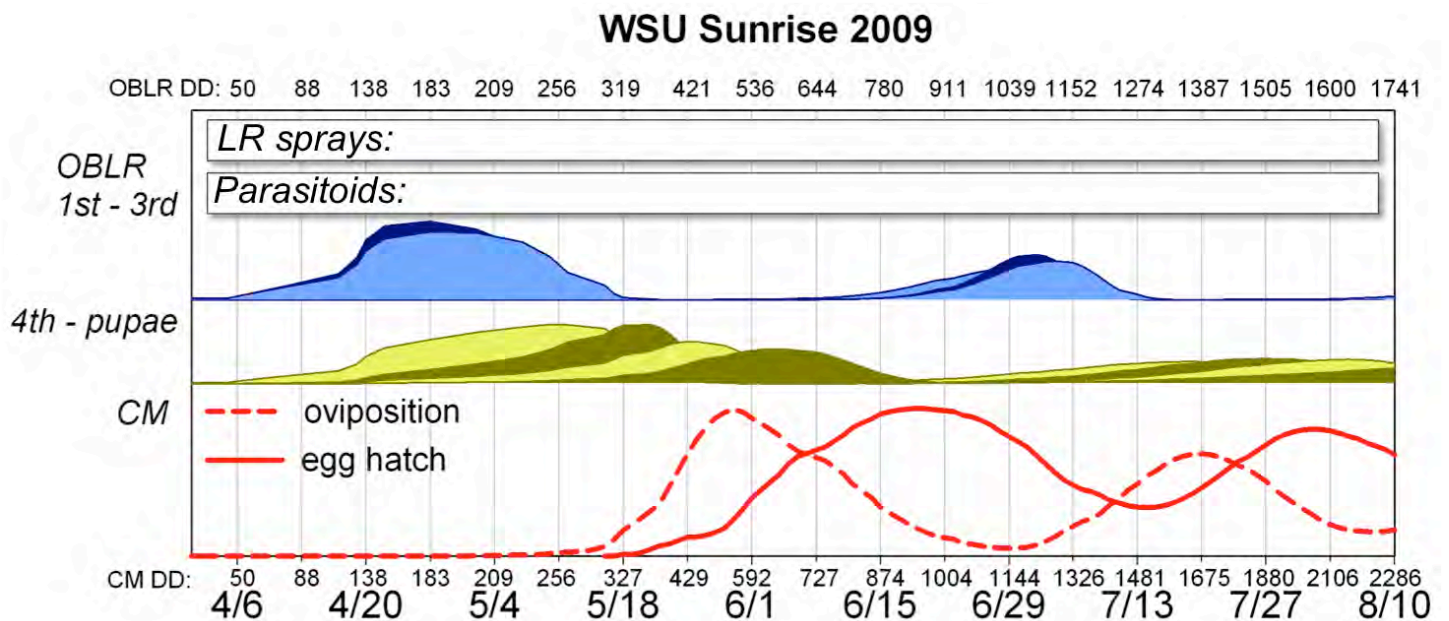
- Pheromone traps
- Sampling (summer generation)
 - 25 shoots from 1 tree per 1.5 acres, count # of larvae
 - larvae in upper half of tree, esp. when more than 10 feet tall
- Retreat when more than 2% of shoots with live larvae
- Overwintering generation
 - between green tip and tight cluster – collect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

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.



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

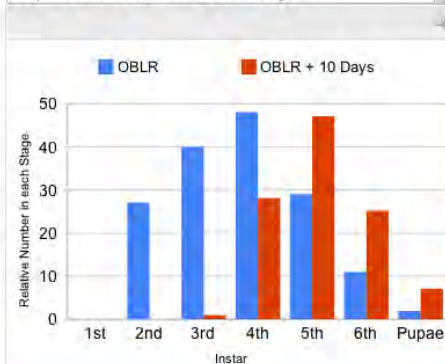
Conditions:

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:

Crop Stage:

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

View Full WSU Spray guide

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

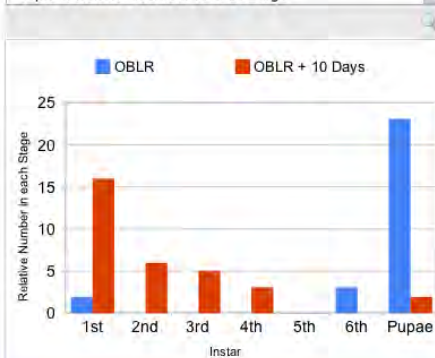
Conditions:

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:

Crop Stage:

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)

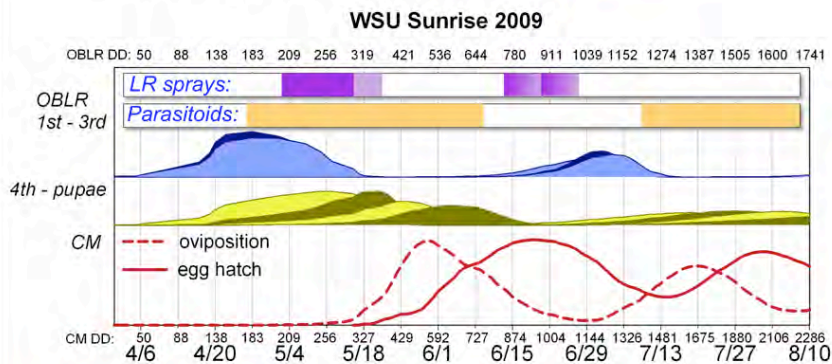
View Full WSU Spray guide

Also see pages 198 & 199 in this workbook

Notes:

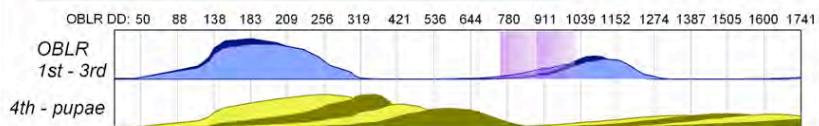
Timing of LR control treatments

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

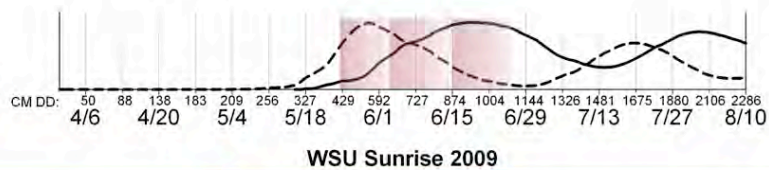


Notes:

Timing of CM and OBLR control treatments



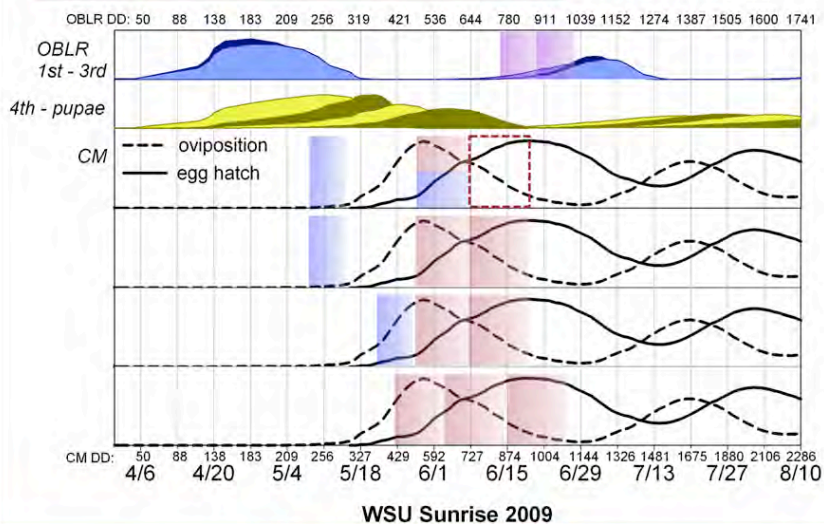
Mating disruption used!



WSU Sunrise 2009

Notes:

Timing of CM and OBLR control treatments



WSU Sunrise 2009

(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)	1 st cover 425 DD (250 DD pbf)	Delayed 1 st cover 525 DD (350 DD pbf)	2 nd cover 625-675 DD (450-500 DD pbf)	Delayed 2 nd cover 725-825 DD (550-650 DD pbf)	3 rd 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 Altacor Assail Calypso virus + Altacor Intrepid Rimon Esteem		May not need 2 nd cover	

pbf = post biofix
Source: Pest Management Transition Project Handbook (<http://pmp.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



Statewide UC IPM Project

Notes:

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)

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

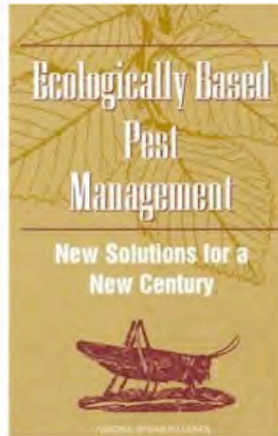


- Stern et al. (1959) 'The ideal material [pesticide] is not one that eliminates all individuals of the pest species . . . [It] is the one that shifts the balance back in favor of natural enemies'

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*



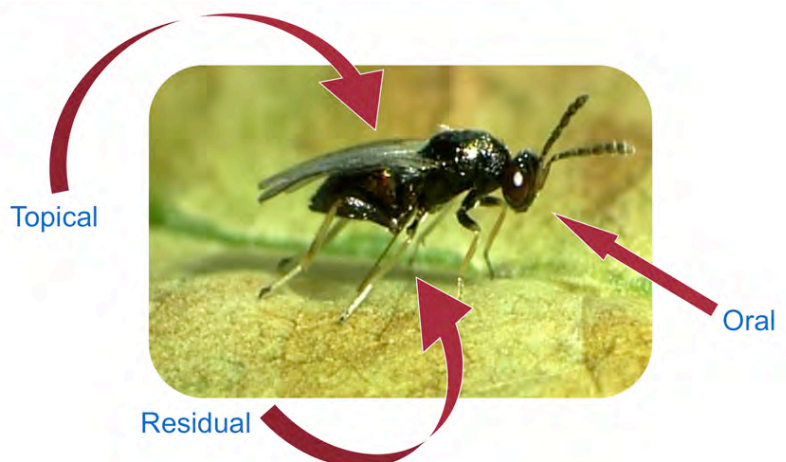
Notes:

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



Notes:

Probable effects in the field

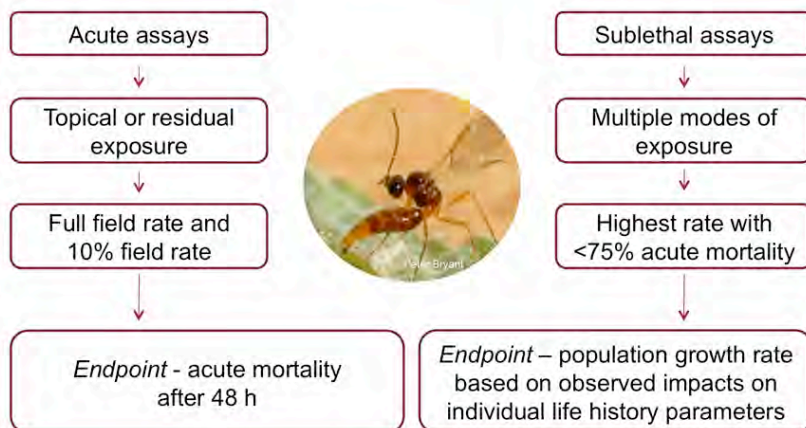
➤ Why not avoid the difficulty of extrapolation and simply test effects on natural enemies directly in the field?

- 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



Notes:

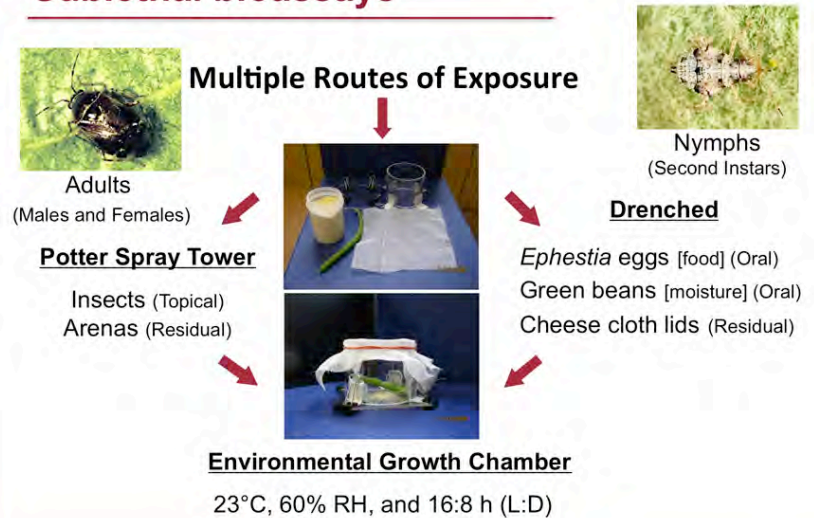
Acute bioassays

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



Notes:

Sublethal bioassays



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:

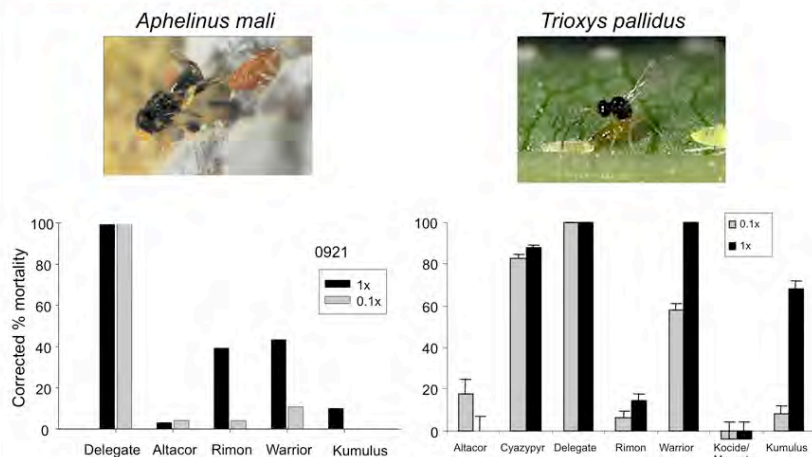
Extrapolation from Bioassays

- 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



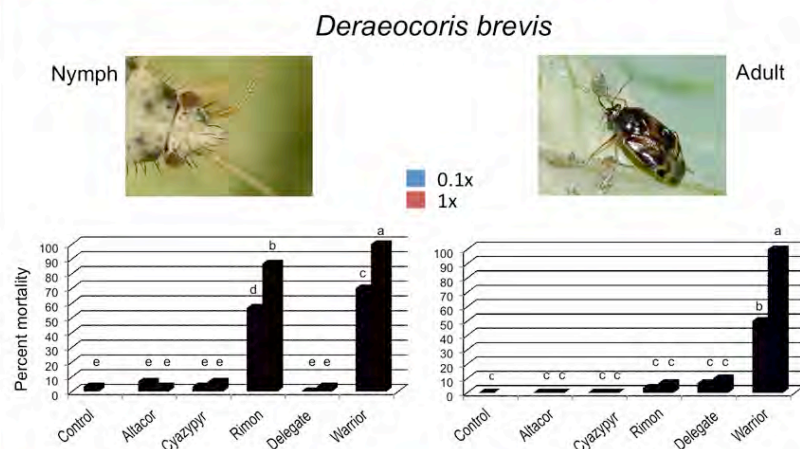
Notes:

Acute effects on parasitoids



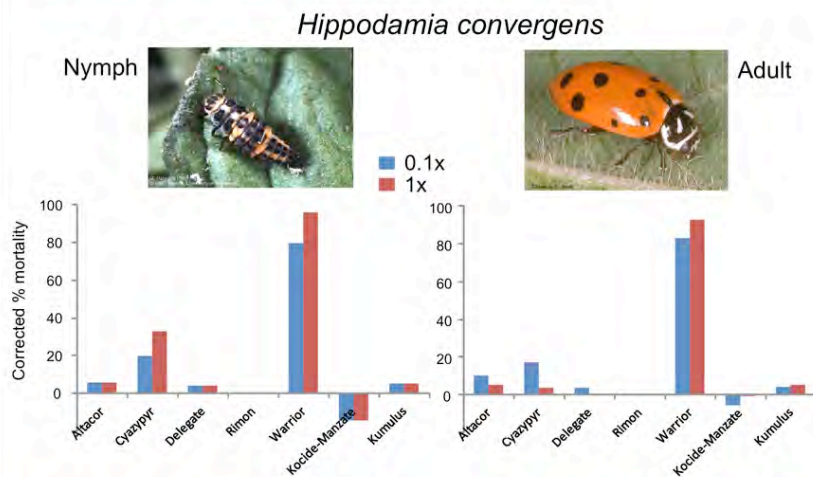
Notes:

Acute effects on predators



Notes:

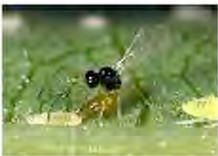
Acute effects on predators



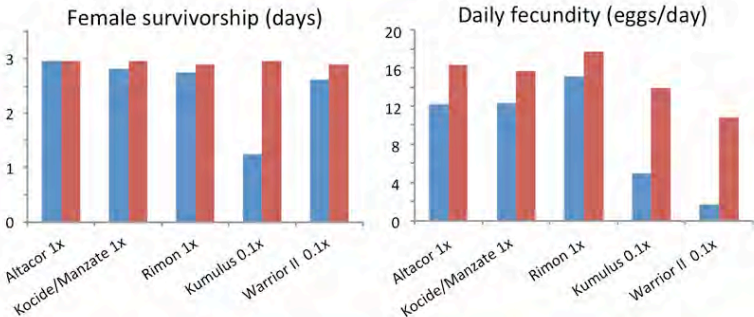
Notes:

Sublethal effects on parasitoids

Trioxys pallidus

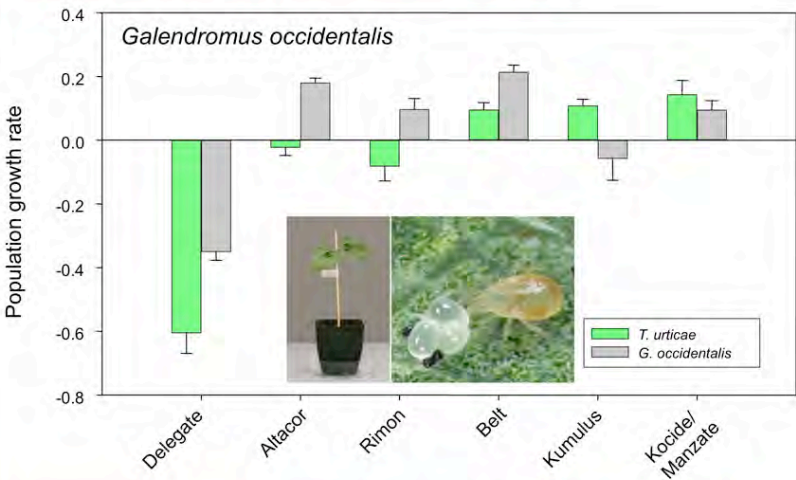


Treatment
Control



Notes:

Sublethal effects on predators



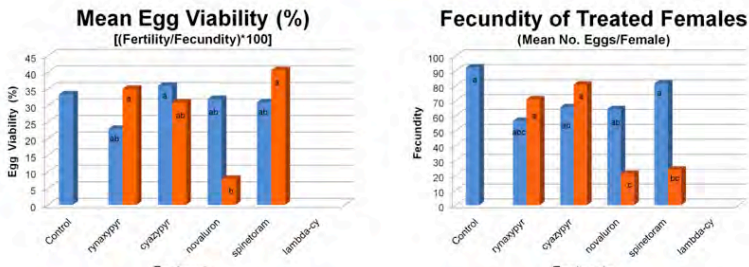
Notes:

Sublethal effects on predators

Deraeocoris brevis



Treatment
Control



Lab Bioassays – Summary of Effects

NE tested	effect measured	Altacor	Cyazypyr	Delegate	Rimon	Warrior	Kumulus	Kocide/Manzate
<i>Aphelinus mali</i>								
	acute mortality, adult parasitoid							
	population growth rate, r							
<i>Trioxys pallidus</i>								
	acute mortality, aphid host							
	acute mortality, adult parasitoid							
	population growth rate, r							
<i>Deraeocoris brevis</i>								
	acute mortality, nymph							
	acute mortality, adult							
	population growth rate, r							
<i>Chrysoperla carnea</i>								
	acute mortality, larva							
	acute mortality, adult							
	population growth rate, r							
<i>Hippodamia convergens</i>								
	acute mortality, larva							
	acute mortality, adult							
	population growth rate, r							
<i>Galendromus occidentalis</i>								
	acute mortality, immature							
	acute mortality, adult							
	population growth rate, r							
<i>Pelegrina aeneola</i>								
	acute mortality, immature							
	acute mortality, adult							
	population growth rate, r							
<i>Misumenops lepidus</i>								
	acute mortality, immature							



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

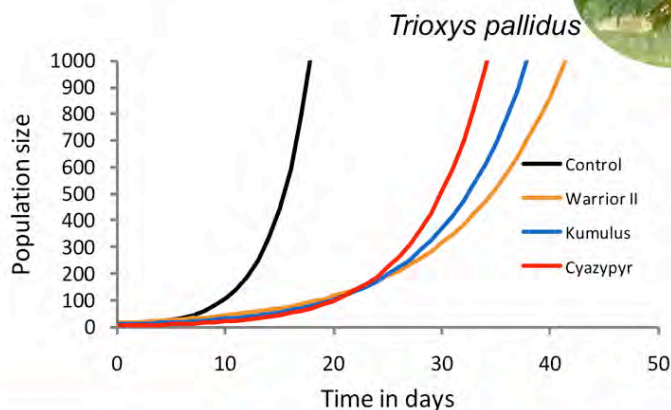


Pesticide	Pop growth rate
Control	0.157
Altacor	0.142
Rimon	0.005
Delegate	-0.261

Notes:

Extrapolation with matrix models

➤ Delay in recovery time



Notes:

Notes:

Field Verification

- Lab bioassays suggest the following ranking for the potential of the tested pesticides to cause disruption of NEs:

Warrior, Delegate
Cyazypyr, Kumulus, Rimon
Kocide/Manzate, Altacor



Notes:

Summary

- Some of the new “low risk” pesticides are not compatible with biocontrol due to sublethal as well as acute effects
- Lab bioassays are a quick way to screen a large number of pesticides for disruptive effects, and are less expensive than field testing
- Population growth indices from ‘worst case’ lab bioassays can be used to rank potential disruptive effects of pesticides for further field verification



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