Invasive Pests
Light Brown Apple Moth And More

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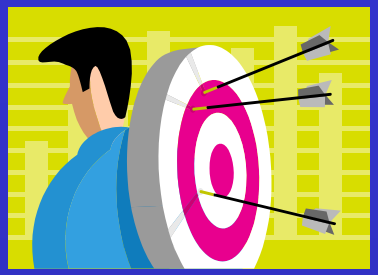
Outline of Presentations

- Why are invasive pests important?
- What are the characteristics of important invasive species?
- What generally happens when an invasive pest is introduced into California? A case study with *Phytophthora ramorum* (Sudden Oak Death) in nurseries.
- Light Brown Apple Moth management in nurseries.

- Light Brown Apple Moth management in berries (M. Bolda)
- Drosophila suzukii management in berries (M. Bolda)

Invasive Species California

- Every 60 days, California gains a new and potentially damaging invasive species.
- Economic loses estimated at $3 billion per year.
- The unique climate and geography of California provides diverse ecosystems which are perfect for the establishment of a diverse variety of new pests.
- Ornamental nurseries usually offer a multitude of potential hosts and environmental conditions !



Ornamental Industry is a Target !

Pest or Pathogen	Ornamental hosts	Industry or Ecosystem Affected
Phytophthora ramorum (SOD)	Rhododendron, Camellia, and others	Oak woodland and forests
Q-biotype silverleaf whitefly (pesticide resistant strain)	Poinsettias, and others	Cotton, melons, vegetables
Glassy-winged sharpshooter (GWSS) and Xylella	Many nursery stock hosts	Grapes
Ralstonia solancearum (cold-tolerant strain)	Geraniums	Potato
Light Brown Apple Moth	Rose, Many	Citrus, grapes, and others

Invasive Species: Characteristics

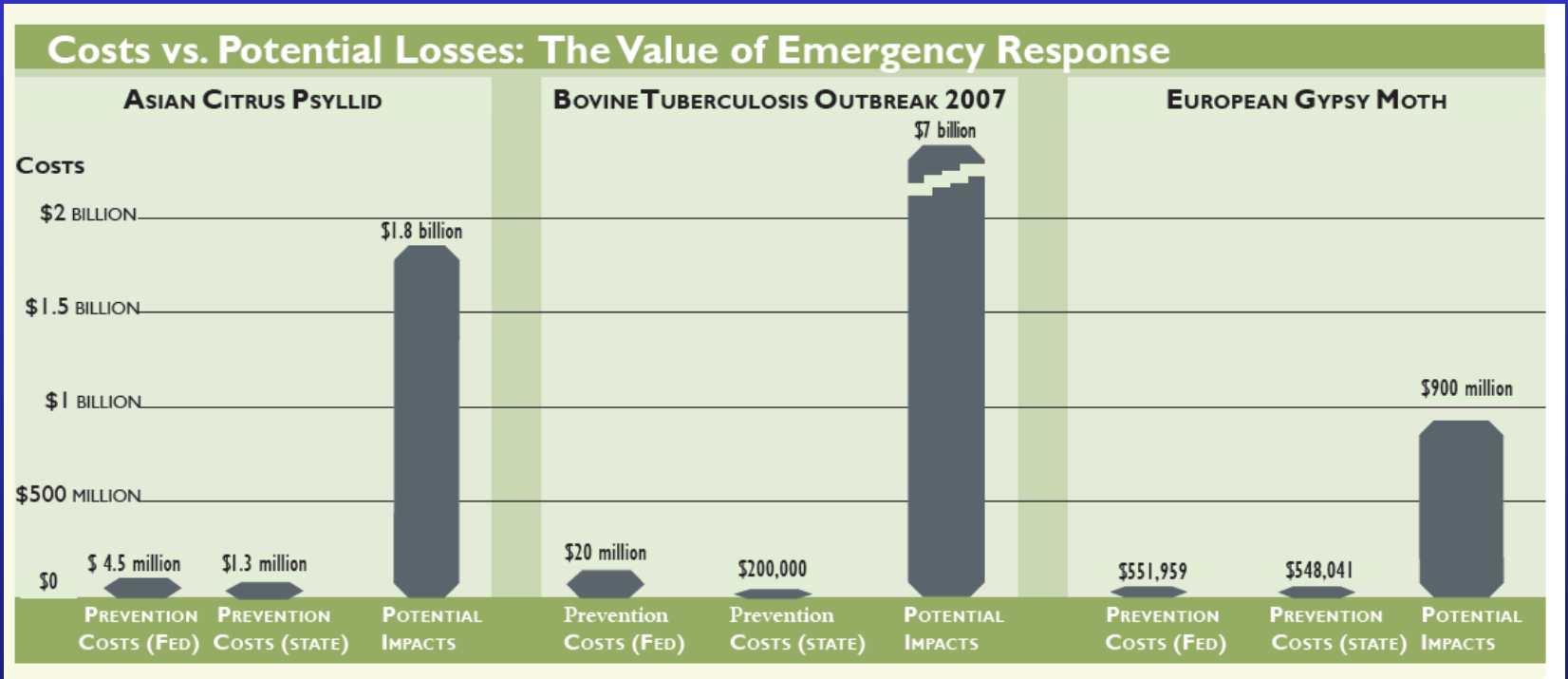
- Many types
  - Insect pests, diseases, weeds, mollusks, etc.
- Out of place
  - Does not occur naturally in a specific area and whose introduction does or is likely to cause economic or environmental harm or harm to human health.
- Biological potential
  - Rapid reproduction, fast growth, wide dispersal capability, tolerate a wide range of environmental conditions, and the ability to feed on a variety of different foods.
- Humans move
  - Usually vectored or moved by human activity of some kind (such as foreign trade and travel).

Often the best single predictor of invasive ability is whether a species is already known to be an invasive pest somewhere else.

Federal and State Agencies Safeguard Agriculture and Natural Resources

- USDA APHIS Plant Protection and Quarantine
- CDFA Plant Health and Pest Prevention Services
- Role to detect, delimit infestation
- Develop regulatory framework
- Science based control strategies
- Environmental compliance

Often worth the fight to eradicate



From: Protecting California from Biological Pollution, Jan. 2009, CDFA

Response to a new invasive pest

1. Risk analysis
2. Detection and Delimitation
3. Regulatory Action
4. Development of Best Management Practices
5. Development of Educational Materials

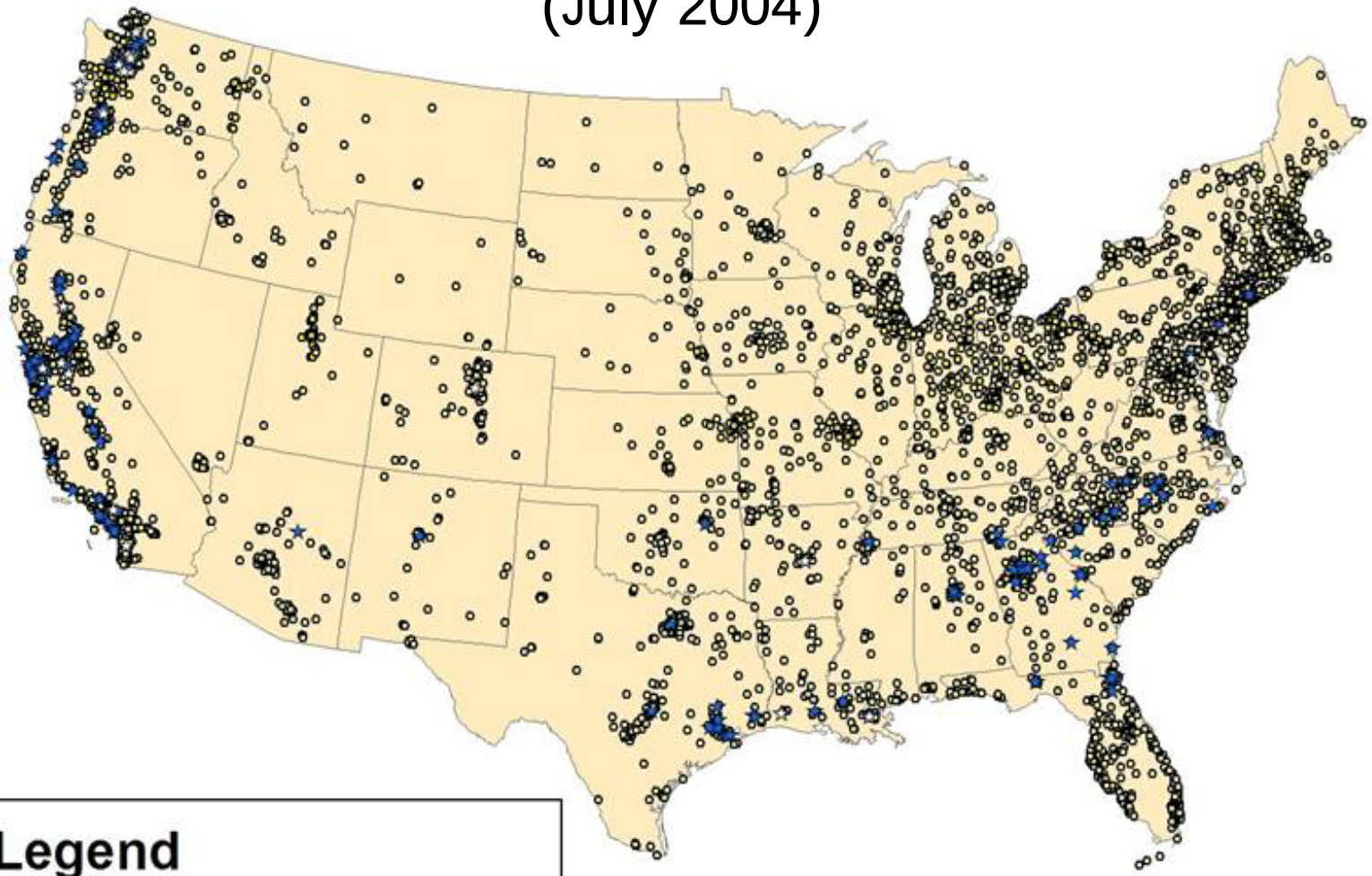

Phytophthora ramorum
Sudden Oak Death
Santa Cruz Mountains,. 1999

Phytophthora ramorum

in nurseries

February 2004, Azusa CA., Camellia

Trace-forwards and positive detections across the U.S. (July 2004)



176 finds in 21 States by the end of 2004

Map: USDA, APHIS, PPQ

Response to a new invasive pest

1. Assessing the risk to agriculture, urban, and natural areas can be difficult

- Sometimes limited knowledge about biology
  - P. ramorum was a previously unknown species.
- Pathogen interactions with new potential hosts and environments could lead to new diseases.
  - P. ramorum was found in woodlands, forests, urban/woodland interface, ornamentals in nurseries and landscapes.
  - P. ramorum is mostly a minor foliar pathogen, but it can kill a 200-year old oak when it infects trunks.
- APHIS relies on best available science to determine risk and regulatory decisions. But sometimes information is limited.
  - At first, information on other Phytophthora species was used to regulate P. ramorum.

Biology and epidemiology

Phytophthora ramorum

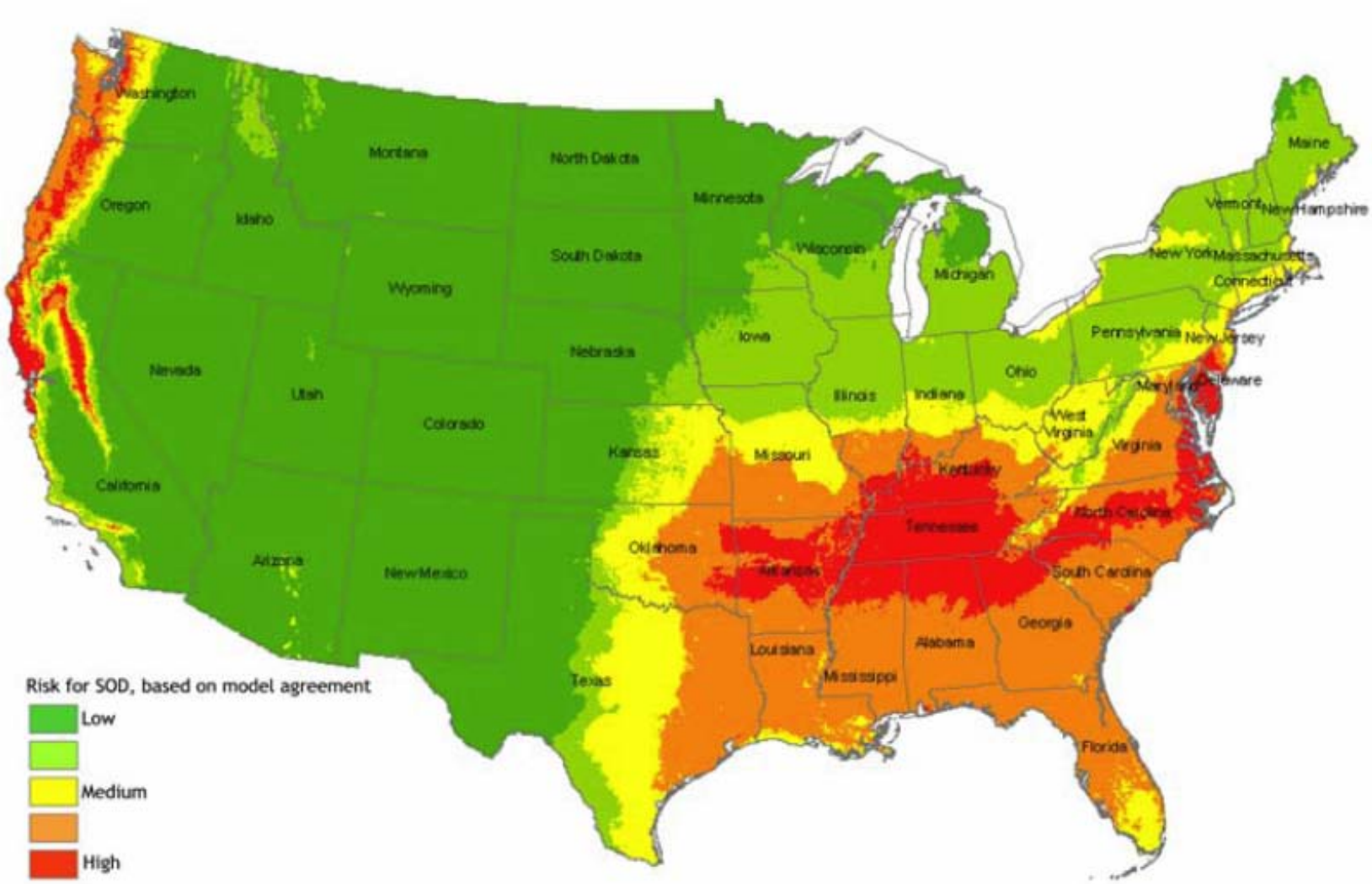
- Funding needed for research (2000). Jump start with funding from U.C. and then USDA Forest Service.
- Later, funding from USDA Agriculture Research Service, APHIS, industry, private foundations.

Biology and epidemiology
Phytophthora ramorum

- A water mold (Oomycete)
- Favorable environment:
  - Wet environments
  - Cool: 20 ^{o}C (optimum) 2 - 26 ^{o}C. (min.-max.)

Biology and epidemiology
Phytophthora ramorum

- Two genotypes are known:
  - A European (A1 mating type primarily) and a North American (A2 mating type). Suggests introduction from a third unknown origin.
- Wide host range of ornamentals and natives:
  - More than 110 plant taxa, many plant families and genera
  - Primarily on foliage, woody hosts



Spatial Modeling of Sudden Oak Death Risk (Kelly, Shaari, Guo & Liu, 2005)

Phytophthora ramorum

Spore types found

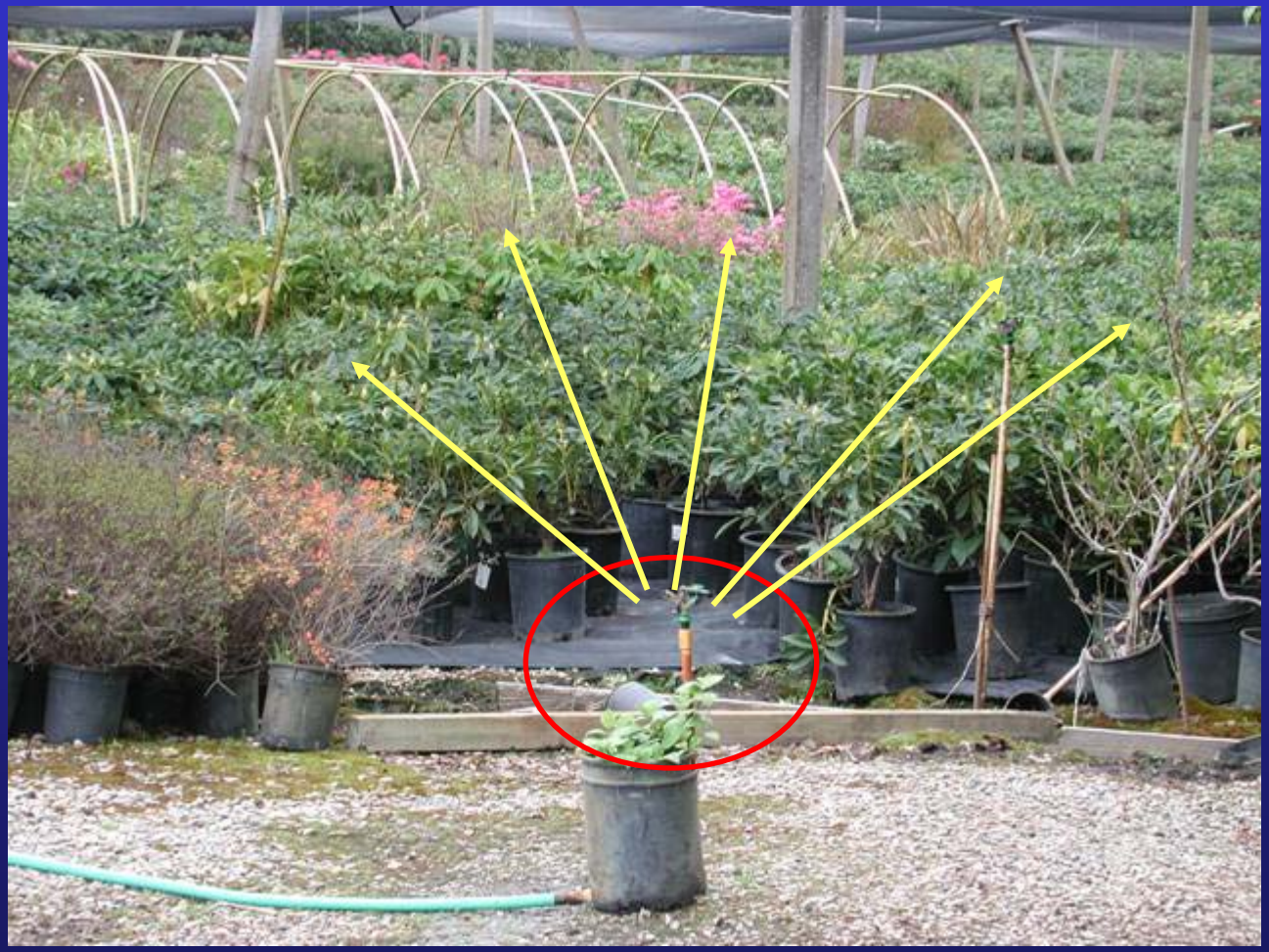
- Sporangia
  - Aerial infectious sporangia can be spread in streams, irrigation water, and between plants.
  - Can produce copious, ephemeral, infectious swimming zoospores.


Sporangia and zoospores

- Chlamydospores
  - Abundant thick-walled spores produced in adverse conditions in plant debris and soil
  - capable of surviving many months


Chlamydospores

P. ramorum spores detected in stream water



Inoculum can be spread on to new nursery and landscape hosts and cause disease

Infested leaf litter: soil inoculum and undetected pathogen movement

Photo: N. Shishkoff, USDA

P. ramorum sporulating on azalea roots

2. Identification and detection

- Images of symptoms on hosts
- Laboratory culture techniques
  - *P. ramorum* cultured on selective media
- DNA fingerprint
  - *P. ramorum* PCR procedures were tested and refined
- Immunoassay laboratory and field tests
  - ELISA for *P.* species and *P. ramorum*

Response to a new invasive pest

3. Regulatory Action

- Federal (APHIS) controls movement of agricultural products between states.
- State (CDFA) controls movement of agricultural products within the state. Regulatory guidelines for inspection and actions established at local / grower level. (Often supported by APHIS).
- Compliance agreements established with agricultural producers with positive detections.

Response to a new invasive pest

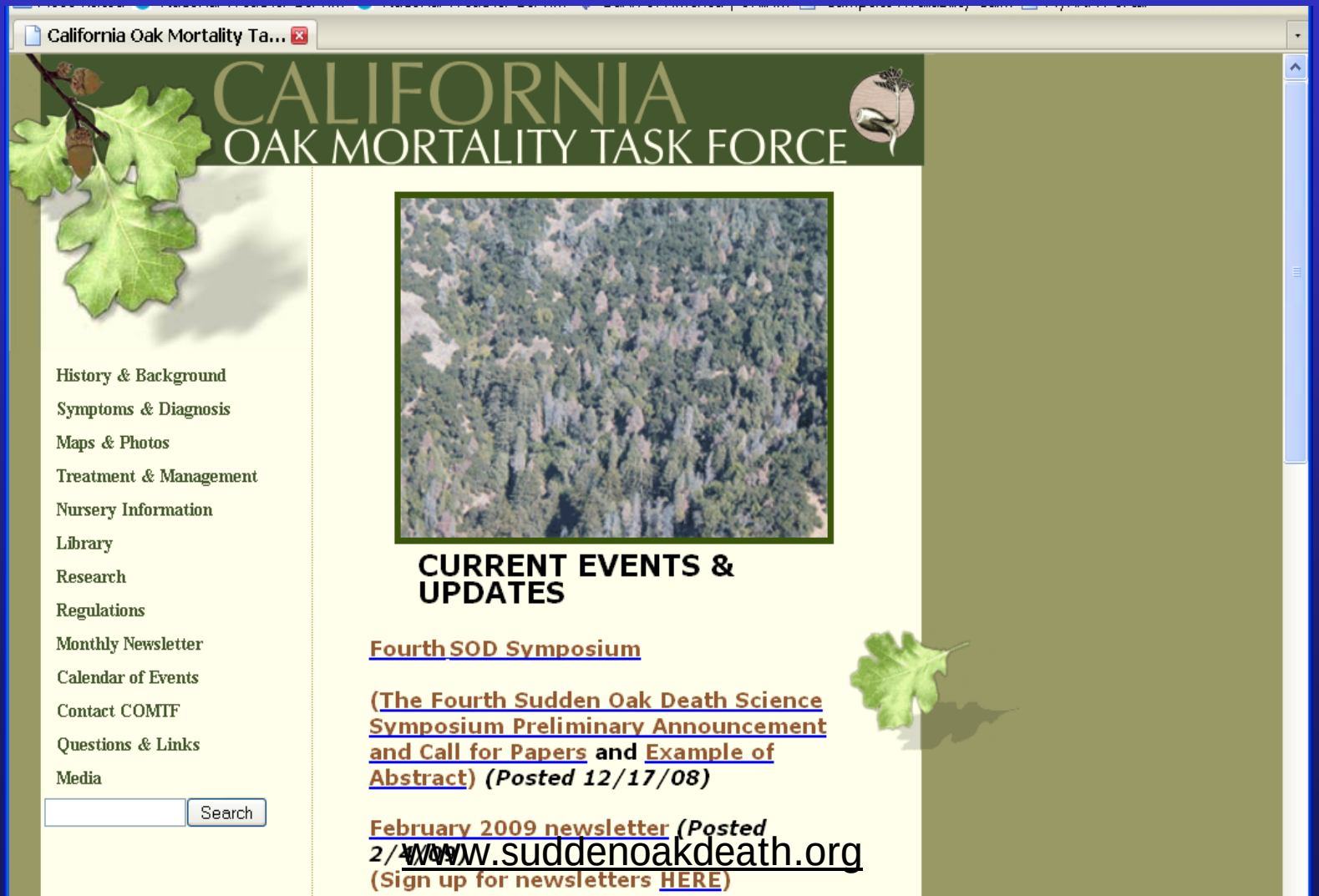
4. Best Management Practices

Exclusion and Prevention of Establishment in Nurseries

- Inspection, scouting, isolation of new plant material if possible, record keeping.
- Cultural practices to prevent establishment. Obtaining and using healthy plant material. Sanitation.
- Chemical treatments to prevent establishment. Keep in mind resistance management too.

Response to a new invasive pest

5. Development of educational material, websites, and training



Nursery Industry
BEST MANAGEMENT PRACTICES
for *Phytophthora ramorum*
- to prevent the introduction or establishment in California nursery operations
Version 1.0

ENDORSEMENTS
CA Association of Nurseries and Garden Centers
Nursery Growers Association
CA Farm Bureau
San Diego Flower and Plant Association
Garden Rose Council
CA Oak Mortality Task Force
California Center for Urban Horticulture, UC Davis
Horticultural Research Institute

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COVER PHOTO
Briggs Nursery in Bonsall, CA. ERIC LARSON, photographer

PUBLICATION 8156

Nursery Guide for Diseases Caused by *Phytophthora ramorum* on Ornamentals: Diagnosis and Management

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http://anrcatalog.ucdavis.edu

INTRODUCTION

Phytophthora ramorum, a newly discovered plant pathogen, has caused widespread mortality in native oaks and tanoaks in many coastal areas of central and northern California and in southwestern Oregon. On oaks, the disease is commonly called sudden oak death because trees typically appear to die rapidly (fig. 1) In infested wildlands (forests and woodlands), the pathogen has been detected on several other trees, shrubs, vines, and herbaceous native plants, where it causes less-destructive leaf blights, stem cankers, and tip dieback.

Camellias, rhododendrons, and other popular ornamental plants are susceptible to *P. ramorum* infection, and the pathogen can be moved long distances through shipments of infected nursery stock. By the end of 2004, the pathogen has been detected on nursery stock and some outplantings in 21 U.S. states and British Columbia. Federal and state quarantines are in effect that require nursery inspections, and if the pathogen is found, affected nursery stock must be destroyed as a means of eradication.

UC PEER REVIEWED

Figure 1. Coast live oak mortality, Santa Cruz County, CA, 1999. Photo: S. Tjosvold.

Grower-oriented Publications

Light Brown Apple Moth Management in Nurseries

Light Brown Apple Moth
LBAM

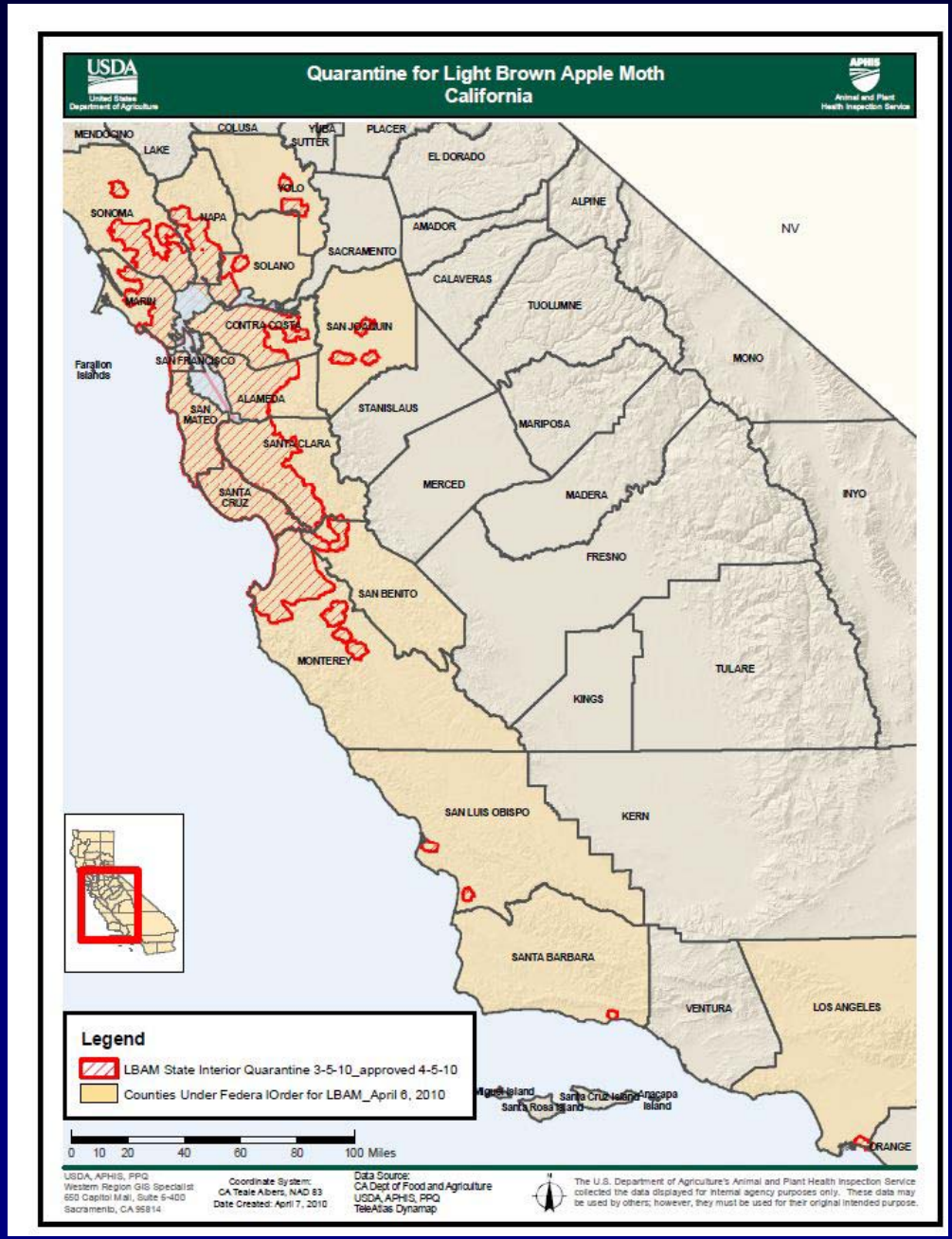
- Why important ?
- Identification
- Basic biology
- Inspecting plants
- Mangement and Treatments
- Resources for more information
- Regulations

LBAM Importance

- A native moth in Australia where it is a pest of apples, pears, oranges and grapes because of associated management costs to eliminate LBAM on exports. Leafroller damage and some fruit damage possible.
- Introduced to Tasmania, New Zealand, British Isles, New Caledonia, Hawaii, and California.
- LBAM has a wide host range, probably 2-4 overlapping generations per year, no winter diapause. Has proven to be adaptable in California.
- Quarantined pest in California and is strictly regulated by CDFA and USDA in agricultural commodities and articles.

LBAM

- First detected in Berkeley, California Feb. 2007
- Detected in many counties, 16 counties federally quarantined
- Most impacted are in cooler coastal regions



Over 2400 square miles are under a State Interior Quarantine

Feb, 2011

20 Most Common LBAM Host Genera, USDA Inspections

Host Scientific Name	Host Common Name	Number of Occurrences
Rubus spp.	Raspberries, Blackberries	122
Alstroemeria	Peruvian Lily	104
Myrica californica	California Myrtle	86
Fragaria sp.	Strawberry	81
Rosa spp.	Roses	61
Ceanothus spp.	California Lilacs	50
Pittosporum spp.	Pittosporums, Cheesewoods	50
Leucadendron spp.	Leucadendrons	45
Vaccinium spp.	Blueberries	43
Rosmarinus sp.	Rosemary	36
Ribes spp.	Ribes	33
Hydrangea sp.	Hydrangeas	32
Salvia spp.	Salvias, Sages	32
Prunus spp.	Plums, Cherries, Peaches, Apricots	31
Malus spp.	Apples	29
Arctostaphylos spp.	Manzanitas, bearberries	27
Boronia	Boronias	23
Rhamnus spp.	Buckthorns	23
Protea spp.	Proteas	22
Citrus spp.	Citrus	21

Leah Gayagas, USDA, Nov 2010

HOST PLANTS

Over 250 plant species, 50 families, and 120 genera.
Herbaceous plants preferred over woody plants
Remember the weeds!

Adiantum sp., *Aguilegia* sp., *Amaranthus* sp., *Arbutus* sp., apple (*Malus domestica*, *Malus* spp.), apricot (*Prunus armeniaca*), *Artemesia* sp., *Astartea* sp., *Aster* sp., avocado (*Persea americana*), *Baccharis* sp., black alder/European alder (*Alnus glutinosa*), blackberry and raspberry (*Rubus* spp.), black poplar (*Populus nigra*), blueberry (*Vaccinium sp.*), *Boronia* sp., *Brassica* sp., *Breynia* sp., broad bean (*Vicia faba*), broadleaf dock (*Rumex obtusifolius*), *Bursaria* sp., butterfly bush (*Buddleia* sp.), *Calendula* sp., *Callistemon* sp., camellia (*Camellia japonica*), *Campsis* sp., capeweed (*Arctotheca calendula*), *Cassia* sp., *Ceanothus* sp., Chinese gooseberry (*Actinidia chinensis*), *Choisya* sp., chrysanthemum (*Chrysanthemum* sp.), citrus (*Citrus* spp.), *Clematis* sp., *Correa* sp., cotoneaster (*Cotoneaster* sp.), *Clerodendron* sp., clover (*Trifolium repens*, *Trifolium* sp.), *Cupressus* sp., curled dock (*Rumex crispus*), currant (*Ribes* sp.), *Cydonia* sp., *Dahlia* sp., *Datura* sp., *Daucus* sp., *Dodonaea* sp., *Eriobotrya* sp., *Eriostemon* sp., *Escallonia* sp., eucalyptus (*Eucalyptus* sp.), euonymus (*Euonymus* sp.), fat-hen (*Chenopodium album*), *Forsythia* sp., *Fortunella* sp., fox's brush (*Centranthus* spp.), *Gelsemium* sp., *Genista* sp., *Gerbera* sp., gorse (*Ulex europaeus*), grape (*Vitis vinifera*, *Vitis* sp.), *Grevillea* sp., *Hardenbergia* sp., hawthorn (*Crataegus* sp.), hebe (*Hebe* spp.), *Helichrysum* sp., hop (*Humulus lupulus*), horn of plenty (*Feijoa sellowiana*), ivy (*Hedera helix*, *Hedera* spp.), jasmine (*Jasminum* spp.), *Juglans* sp., kiwifruit (*Actinidia deliciosa*), *Lathyrus* sp., *Lavendula* sp., *Leucodendron* sp., *Leptospermum* sp., *Linus* sp., litchi (*Litchi chinensis*), *Lonicera* sp., alfalfa (*Medicago sativa*), *Lupinus* sp., *Lycopersicum* sp., *Macadamia* sp., malabar ebony (*Diospyros* sp.), *Mangifera* sp., *Melaleuca* sp., *Mentha* sp., *Mesembryanthemum* sp., *Michelia* sp., *Monotoca* sp., montbretia (*Crocosmia* sp.), *Myoporum* sp., oak (*Quercus* sp.), *Oxalis* sp., *Parthenocissus* sp., peach (*Prunus persica*), pear (*Pyrus* sp.), *Pelargonium* sp., *Persoonia* sp., *Petroselinum* sp., persimmon (*Diospyros kaki*), *Philadelphus* sp., *Photinia* sp., *Pittosporum* sp., pine (*Pinus* muricata, *P.* radiata, Pinus sp.), plantain / ribwort (*Plantago lanceolata*), *Platysace* sp., *Polygala* sp., *Polygonum* sp., poplar and cottonwood (*Populus nigra*, *Populus* sp.), potato (*Solanum tuberosum*), privet (*Ligustrum vulgare*, *Ligustrum* sp.), *Pteris* sp., *Pulcaria* sp., *Pyllanthus* sp, *Pyracantha* sp., *Ranunculus* sp., *Raphanus* sp., *Reseda* sp., raspberry and boysenberry (*Rubus idaeus*, *Rubus* sp.), rose (*Rosa* sp.), *Salvia* sp., *Senecio* sp., Scotch broom (*Cytisus scoparius*), *Sida* sp., *Sisymbrium* sp., *Smilax* sp., *Sollya* sp., St. John's wort (*Hypericum perforatum*), strawberry (*Fragaria* sp.), *Tithonia* sp., *Trema* sp., *Triglochin* sp., *Urtica* sp., *Viburnum* sp., *Vinca* sp., wattle (*Acacia* sp.), willow (*Salix* sp.).

Pest Exclusion

LBAM can be introduced on nursery stock

- Know crop risk
- Know where incoming nursery stock is coming from
  - Location, and grower
- Inspect incoming shipments and returns
- “Quarantine” new plants, propagative material and plant returns.
- Maintain good weed control
- Inspect landscape plantings in and surrounding the nursery

Pest Exclusion

LBAM can be introduced from surroundings

Pest Exclusion

LBAM can be introduced from surroundings

Strategic monitoring
Look for LBAM life stages and symptoms

LBAM life stages

Adult moth

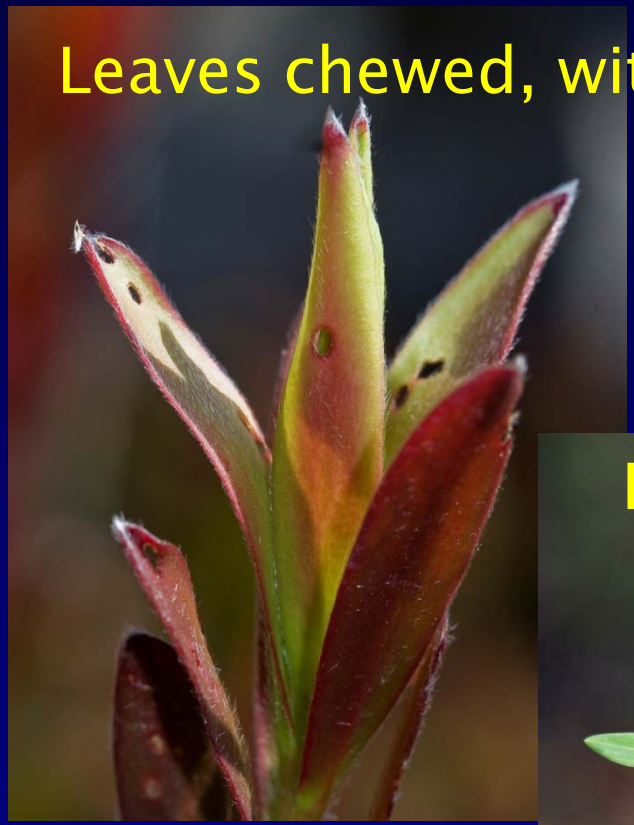
Egg mass

Pupa

Larva

Symptoms at shoot tips

Leaves chewed, with holes



Leaves distorted

Leaves bound together with silk-like webs or threads

Trap Monitoring

Pheromone traps

- Selective synthetic pheromone attracts migrating male moths
- Placed at nursery perimeters near known infestation
- Hung above crop
- Use USDA / State official detection data

A detection of a male LBAM adult does not result in regulatory action

Male LBAM pheromone attractant in Jackson trap

Other Trapping Methods

Bait bucket-traps

- Terpinyl acetate and brown sugar solution
- Vinegar (acetic acid)
- Port wine

Ultraviolet-light trap

Actions and Treatments

- **LBAM detection by official inspectors**
  - **Will trigger a**ctions and treatments dictated by regulatory officials.
- **LBAM** "suspects" **detected by in-house inspections** should be quickly acted on.
  - May have to increase in-house monitoring frequency or intensity in the area of infestation.
  - Physically remove and destroy infestation.
  - Pesticide treatment.

Light Brown Apple Moth Management

Sanitation, exclusion, scouting

Insecticides

- *Bacillus thuringiensis kurstaki* (DiPel DF and others)
- Spinosad (Conserve, Entrust)
- Insect growth regulators (Intrepid)
- Pyrethroids
- Carbamates and organo-phosphates
- Horticultural oils
- Others

Biological control – parasitoids

- UC and CDFA research being conducted on parasitoids of California native leafrollers that may also parasitize LBAM.

Sterile Insect Treatment (SIT)

- USDA facility in Moss Landing developing mass rearing facility for sterile moths

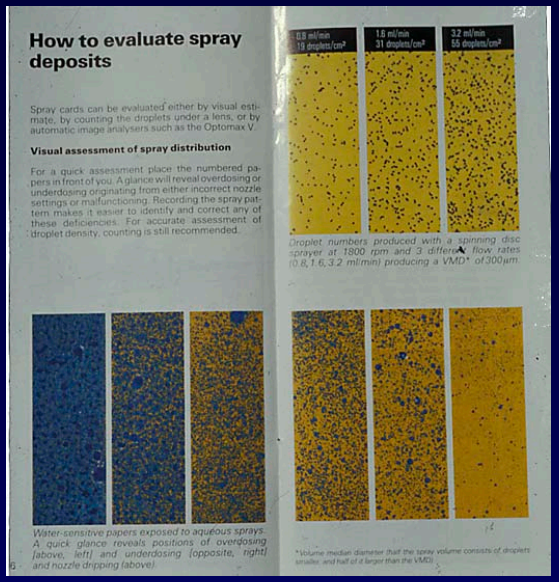
Pheromone mating disruption

- Synthetically derived LBAM pheromones are readily available for this use

Chemical group	Active ingredient	Product examples	CDFA Approved	Comments
Biological	*Bacillus thuringiensis* ssp. *Kurstaki*	Crymax Dipel Pro	Yes Yes	Best on small larvae. Larvae must ingest to be effective. Residual: up to 7 days
Carbamate	cabaryl	Sevin	Yes	Active on all larval stages. Residual: up to 14 days
Organophosphate	chlorpyrifos dimethoate imidan	Dursban DuraGuard Chlorpyrifos-Pro Dimethoate 400 Phosmet	Yes Yes Yes Yes Yes	Active on all larval stages. Residual: up to 14 days
Insect growth regulator	diflubenzuron novaluron tebufenozide methoxyfenozide	Adept Pedestal Confirm Intrepid	No No Yes Yes	Best on small larvae. Residual 7-21 days
Mineral	cryolite Superior oil	ProKil Cryolite Kryocide Bonide All Seasons Purespray Green Sunspray Ultrafine	No No Yes Yes No	Larvae stomach poison Eggs smothered and desiccated. Oil must cover eggs.
Spinosyns	spinosad	Conserve Entrust	Yes Yes	Residual: up to 7 days Organic label
Pyrethroids	lambda-cyhalothrin deltamethrin	Scimitar Suspend	Yes Yes	Residual 7-21 days

Evaluation of Spray Application With Water Sensitive Paper

TeeJet Spraying Systems Co.



How to evaluate spray deposits

Spray cards can be evaluated either by visual estimate, by counting the droplets under a lens, or by automatic image analysers such as the Optomax V.

Visual assessment of spray distribution

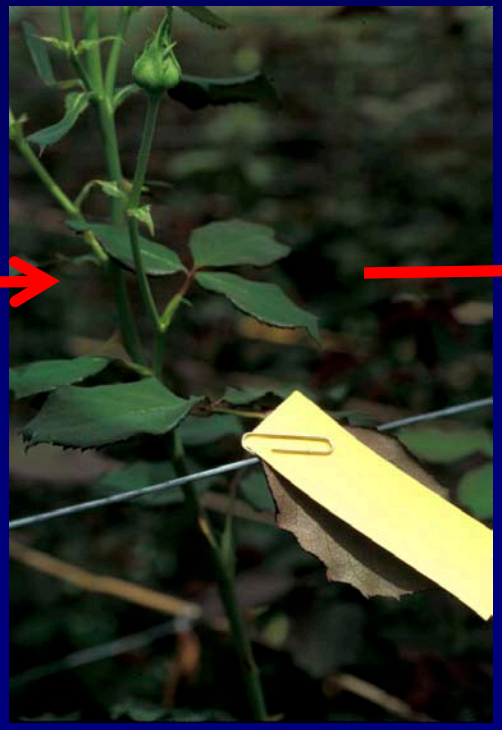
For a quick assessment place the numbered papers in front of you. A glance will reveal overdosing or underdosing originating from either incorrect nozzle settings or malfunctioning. Recording the spray pattern makes it easier to identify and correct any of these deficiencies. For accurate assessment of droplet density, counting is still recommended.

0.8 ml/min 18 droplets/cm² | 1.6 ml/min 31 droplets/cm² | 3.2 ml/min 55 droplets/cm²

Droplet numbers produced with a spinning disc sprayer at 1800 rpm and 3 different flow rates (0.8, 1.6, 3.2 ml/min) producing a VMD of 300µm.*

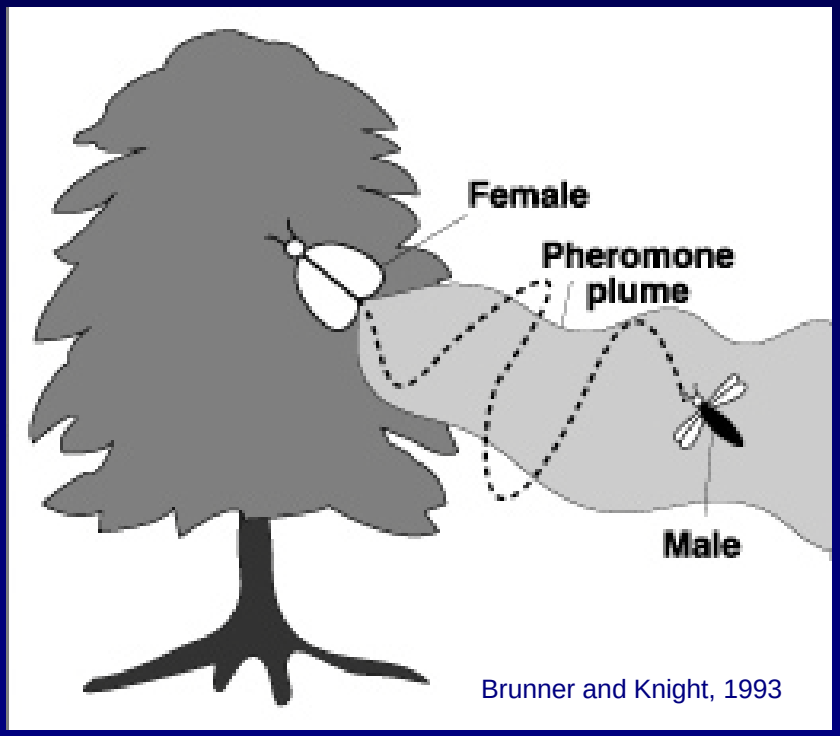
Water-sensitive papers exposed to aqueous sprays. A quick glance reveals positions of overdosing (above, left) and underdosing (opposite, right) and nozzle dripping (above).

** Volume median diameter (half the spray volume consists of droplets smaller, and half of it larger than the VMD).*



Pheromone Mating Disruption

Management Theory

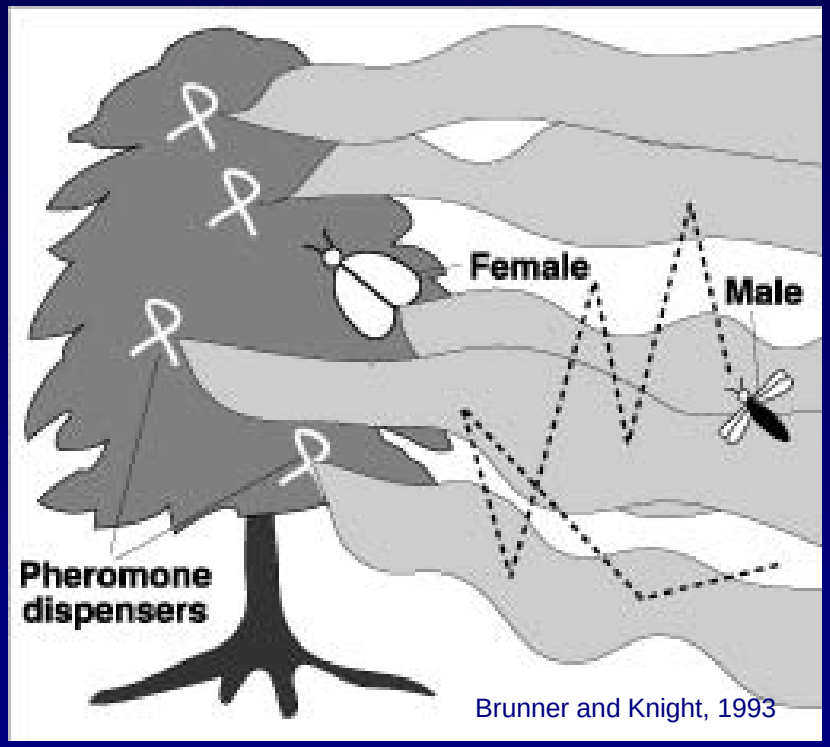


Pheromone

- Chemicals produced by female moths to attract a male of the same species
- Male moths fly upwind, following a pheromone plume to locate a female

Pheromone Mating Disruption

Management Theory



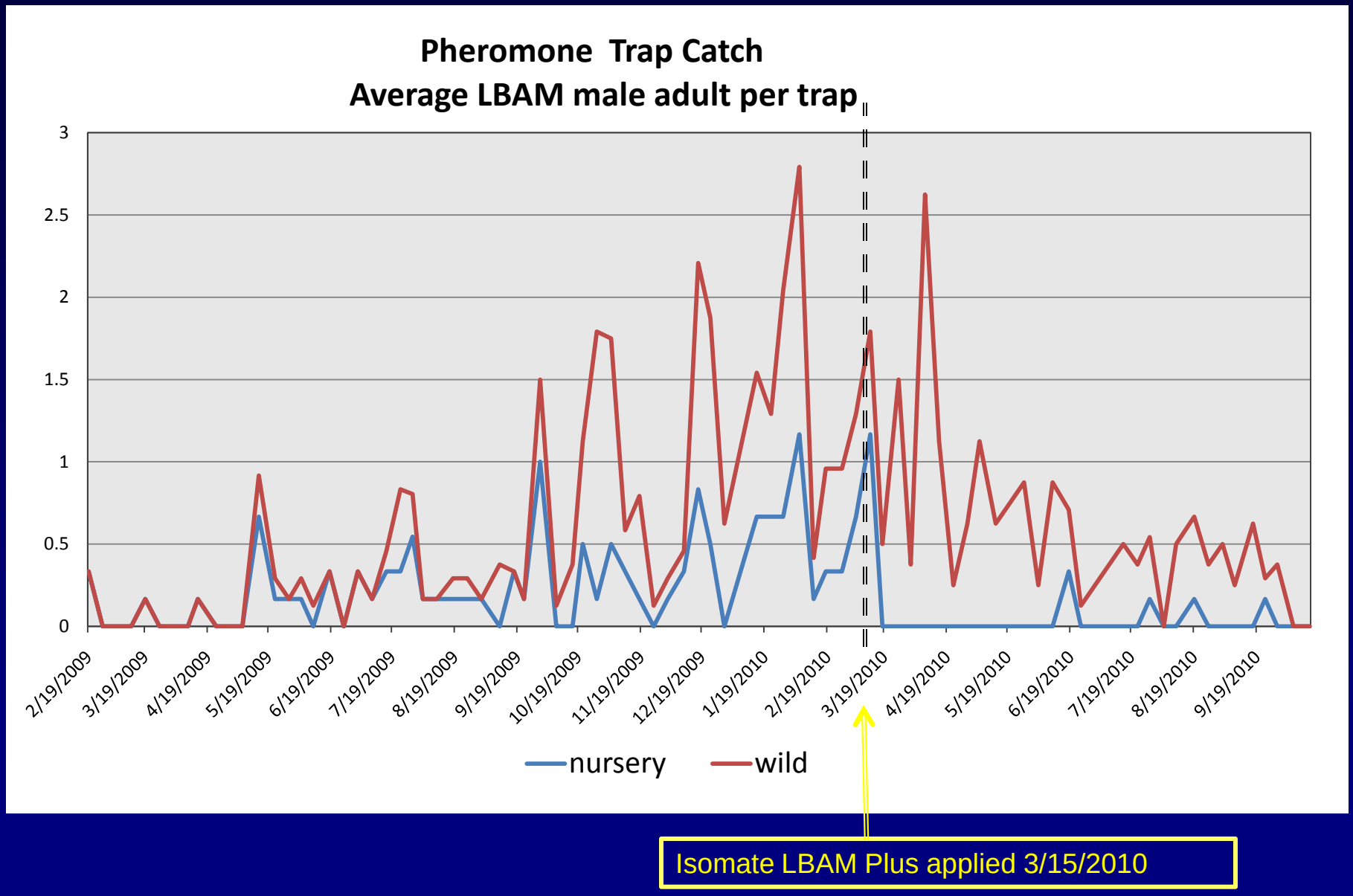
Synthetic Pheromone

- Applied in mass to the field in dispensers
- Male moth can not orient to female and does not successfully mate
- Conventional recommendation is to use large (> 10 A) and uniform, contiguous areas

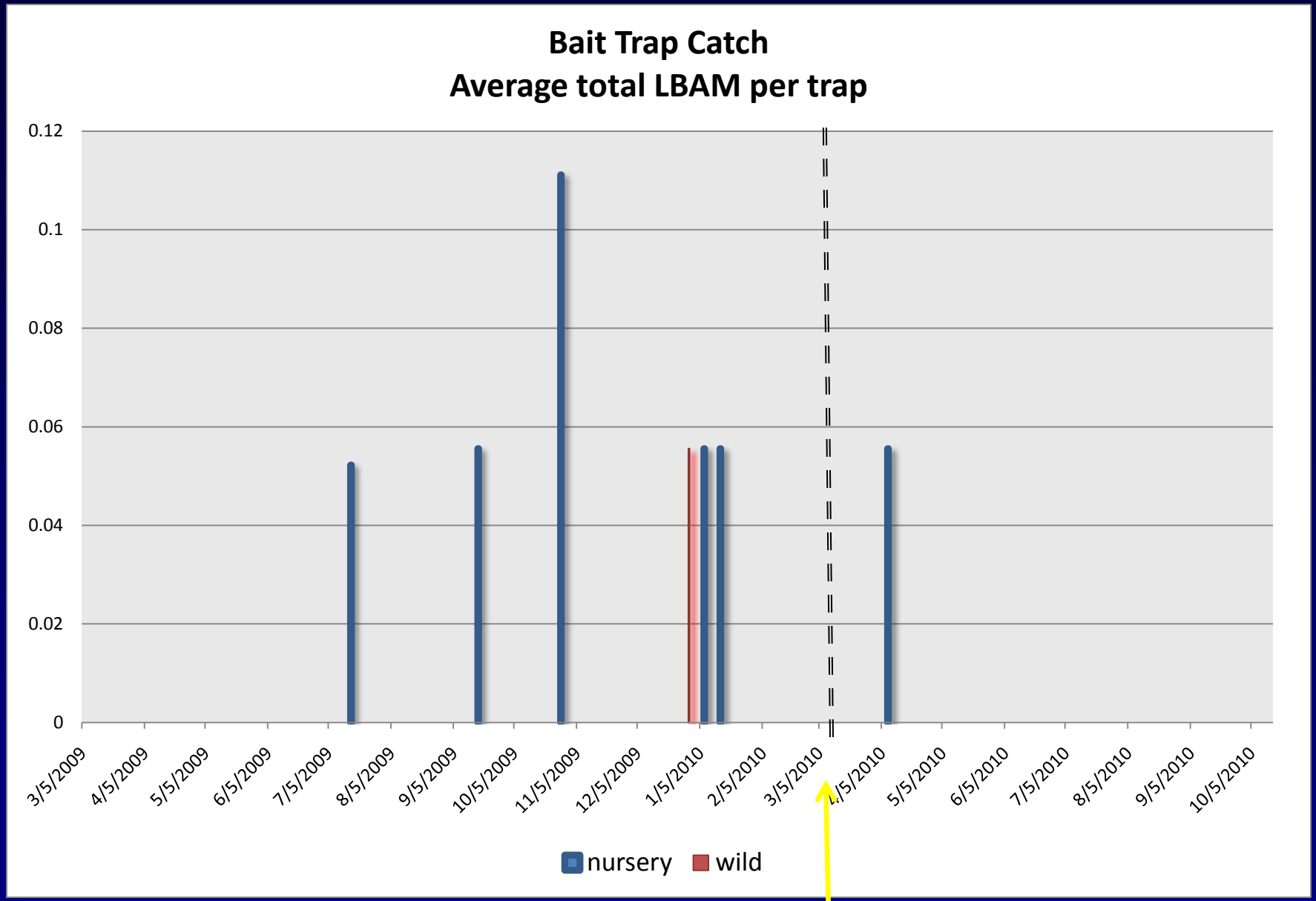
Isomate ® LBAM Plus Application in Nurseries

300 twist ties per Acre = 13 X 13 foot square

NURSERY 1


Pheromone Trap Catch
Average LBAM male adult per trap
3
2.5
2
1.5
1
0.5
0
2/19/2009
3/19/2009
4/19/2009
5/19/2009
6/19/2009
7/19/2009
8/19/2009
9/19/2009
10/19/2009
11/19/2009
12/19/2009
1/19/2010
2/19/2010
3/19/2010
4/19/2010
5/19/2010
6/19/2010
7/19/2010
8/19/2010
9/19/2010
nursery
wild
Isomate LBAM Plus applied 3/15/2010

NURSERY 1


Bait Trap Catch
Average total LBAM per trap
0.12
0.1
0.08
0.06
0.04
0.02
0
3/5/2009
4/5/2009
5/5/2009
6/5/2009
7/5/2009
8/5/2009
9/5/2009
10/5/2009
11/5/2009
12/5/2009
1/5/2010
2/5/2010
3/5/2010
4/5/2010
5/5/2010
6/5/2010
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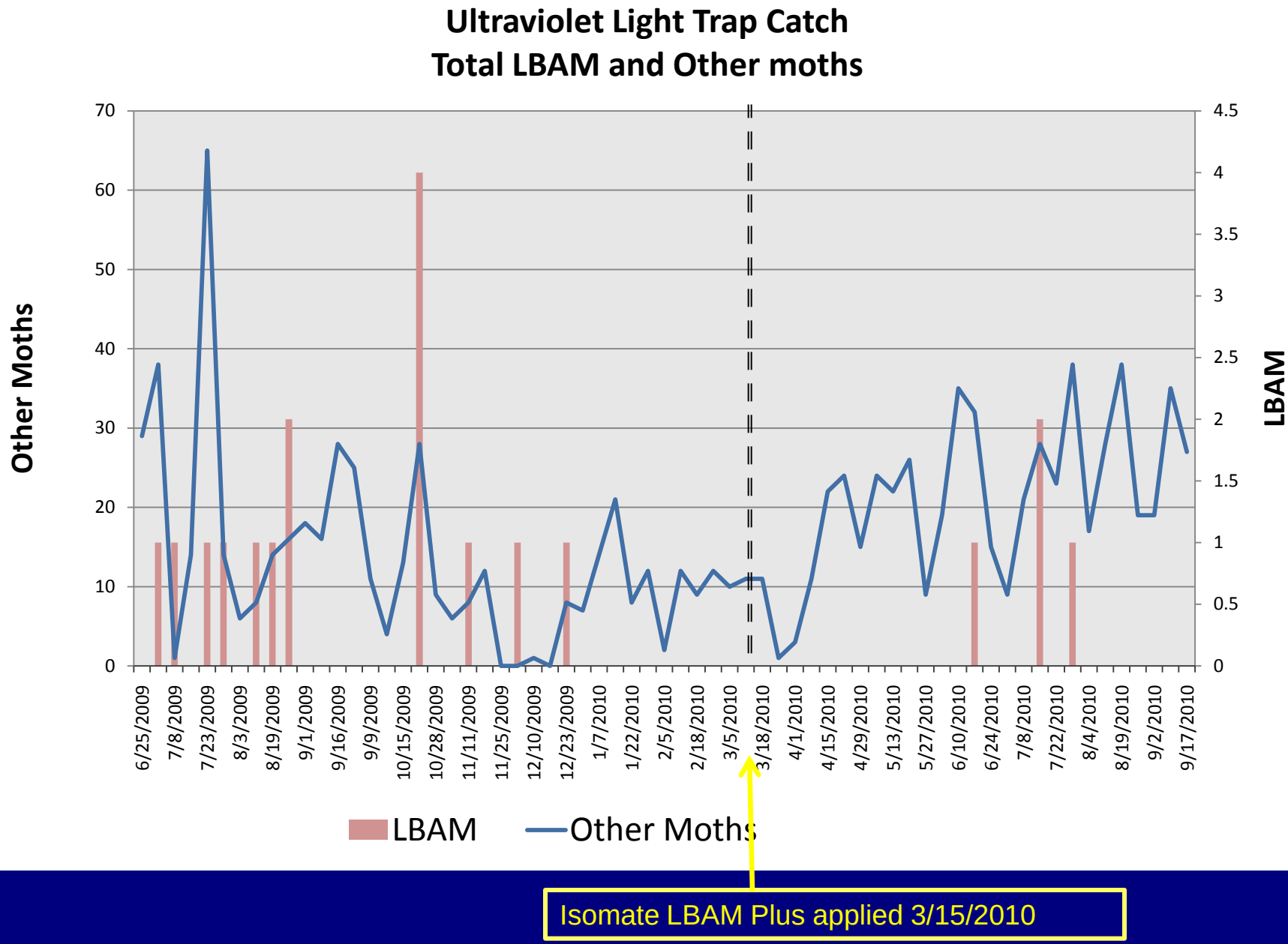
9/5/2010
10/5/2010
nursery
wild
Isomate LBAM Plus applied 3/15/2010

NURSERY 1

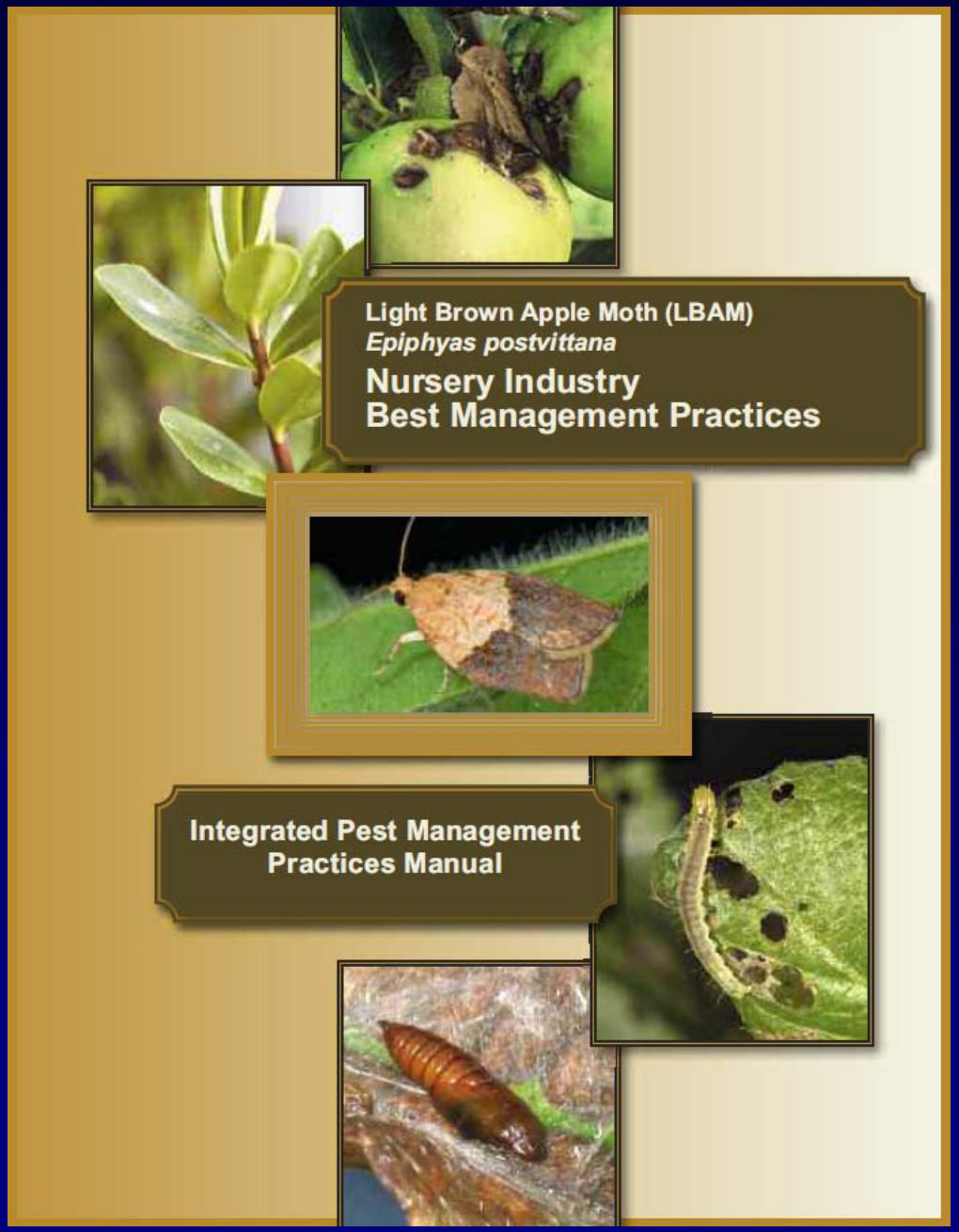

Ultraviolet Light Trap Catch
Total LBAM and Other moths
Other Moths
LBAM
70
60
50
40
30
20
10
0
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
6/25/2009
7/8/2009
7/23/2009
8/3/2009
8/19/2009
9/1/2009
9/16/2009
9/9/2009
10/15/2009
10/28/2009
11/11/2009
11/25/2009
12/10/2009
12/23/2009
1/7/2010
1/22/2010
2/5/2010
2/18/2010
3/5/2010
3/18/2010
4/1/2010
4/15/2010
4/29/2010
5/13/2010
5/27/2010
6/10/2010
6/24/2010
7/8/2010
7/22/2010
8/4/2010
8/19/2010
9/2/2010
9/17/2010
LBAM
Other Moths
Isomate LBAM Plus applied 3/15/2010

USDA Positive LBAM Larval Finds

Post Mating Disruption Implementation

March 2010 to September 2010

★ Nine positive finds during this period



Resources

Website on LBAM:
www.cdfa.ca.gov/LBAM

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