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Light Brown Apple Moth in California:

Quarantine, Management, and Potential Impacts

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In March 2007 the presence of the light brown apple moth (LBAM), *Epiphyas postvittana*, was confirmed in California by the U.S. Department of Agriculture Animal and Plant Health Inspection Service (APHIS). This is the first time this pest has been detected in the continental United States. It was first found in Alameda County and as of July 2007 has been found in the San Francisco Bay area counties of Alameda, Contra Costa, Marin, Napa, San Francisco, Santa Clara, San Mateo, and Solano, in the central coast counties of Monterey and Santa Cruz, and in Los Angeles County. APHIS considers LBAM to be a High-Risk pest and the California Department of Food and Agriculture (CDFA) considers it to be a Class A pest. Because of this, CDFA issued a State Interior Quarantine order restricting intrastate shipment of plant material from counties where LBAM has been found. APHIS later issued a Federal Domestic Quarantine order on May 2, 2007, with restrictions on interstate shipment of plant material.

The purpose of this publication is to help readers:

- Understand why LBAM is subject to quarantine regulations
- Understand the difference between controlling pests that are regulated under a quarantine and managing them in an integrated pest management program
- Learn about LBAM biology and identification
- Learn how to send in a sample for identification
- Become familiar with potential IPM alternatives that might be used in conjunction with eradication efforts
- Learn about possible pesticide treatments for LBAM and how to mitigate their impact on the environment
- Understand possible impacts on various sectors of agriculture and residential areas

While the document generally describes current CDFA and APHIS quarantine regulations and the LBAM situation in California, the legal and latest information, including maps of quarantined areas, can be found on the CDFA LBAM Web site (http://www.cdfa.ca.gov/phpps/PDEP/lbam/lbam_main.html).

Figure 1. Female (left) and male light brown apple moths. Used with the permission of D. Williams, State of Victoria Department of Primary Industries.

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LBAM: A Class A Pest

Pests are classified by CDFA according to their potential to cause harm to California's agriculture and environment. Five classifications are defined. Class A pests are defined as organisms "of known economic importance subject to state (or commissioner when acting as a state agent) enforced action involving: eradication, quarantine regulation, containment, rejection, or other holding action." For definitions of all pest classes, see the PlantPestRatings.pdf file (using the search function) on the CDFA Web site (http://www.cdfa.ca.gov).

The A classification is designed to prevent further spread to other parts of the state and expansion of quarantine regulations to those areas and possibly the entire state. The classification also allows implementation of efforts to eradicate it from the locations where it currently occurs.

CDFA classifies LBAM as a Class A pest because

- It is potentially damaging to a wide range of plant species.
- It does not occur elsewhere in the U.S. or in most other countries.
- Were it to become established in California, quarantine restrictions and prohibitions on shipments would likely have severe impacts on agricultural industries.

Because LBAM occurs in only a limited number of locations (Australia, New Zealand, New Caledonia, Hawaii, Great Britain, Ireland), international quarantines, prohibitions against shipments, or phytosanitary certification of fresh plant products from infested locations within California have been instituted and will most likely continue to be. The primary reason for the A classification is the severe economic loss that such measures would cause industries that ship fresh plant products.

LBAM has a host range that includes many trees and ornamental species, giving it the potential to cause serious damage to natural areas and urban settings as well as to agricultural crops. Nursery products are particularly affected because many of them are LBAM hosts that are shipped outside the affected counties, to other states, and on the international market. It is not known how damaging the pest would be if it were to become established in California. LBAM is a serious pest of grapes, citrus, pome fruits, stone fruits, and kiwifruit in Australian areas that have a climate similar to that of California's Central Valley and is a major introduced pest in New Zealand, where it is favored by the cooler climate. LBAM has not become a serious pest in Hawaii and is common only at higher elevations there. If eradication of LBAM is unsuccessful and it does become established in California, quarantine restrictions and export prohibitions would likely be devastating to some commodity industries. For example, Mexico suspended importation of a number of commodities from quarantined counties on May 10, 2007. Canada implemented quarantine restrictions effective on June 25, 2007.

Quarantine Regulation of LBAM

Quarantine regulations instituted by CDFA and APHIS are aimed at preventing spread of LBAM to other areas of California and to other states. The Administrator of APHIS lists as regulated those areas of the state where LBAM has been confirmed to be present, where the Administrator has reason to believe LBAM is present, or areas that cannot be separated for quarantine enforcement purposes from infested areas. **APHIS will not quarantine the entire state** if CDFA adopts quarantine regulations that are essentially the same as those imposed by APHIS, and if those regulations are considered sufficient to prevent interstate spread of LBAM. Under the quarantine regulations, there is a zero tolerance for LBAM in plant products being shipped from quarantine areas.

As of September 10, 2007, the counties of Alameda, Contra Costa, Los Angeles, Marin, Monterey, Napa, San Francisco, Santa Clara, Santa Cruz, San Mateo, and Solano had been designated as quarantined areas by APHIS and CDFA. The quarantine orders specify the areas designated as quarantined, what products are regulated by the quarantine, and what conditions must be met for movement of regulated products from the quarantine areas. **Check the CDFA Web site regularly for updates.**

- Federal Domestic Quarantine Order for LBAM (http://www.cdfa.ca.gov/phpps/PDEP/lbam/pdfs/LBAM_FederalOrder.pdf)

- State Interior Quarantine for LBAM (http://pi.cdfa.ca.gov/pqm/manual/htm/419.htm)

The quarantine orders affect the following plant products:

- Nursery stock
- Cut flowers, garlands, wreaths or greenery of any plants
- Trees and bushes, including cut Christmas trees
- Green waste (dead or dying plants and plant parts)
- Fruits and vegetables
- Any other harvested plant parts capable of sustaining LBAM
- Possible carriers including equipment used in growing, harvesting, processing, and transporting host plants, plant parts, and green waste residues

REGULATORY REQUIREMENTS

Specific procedures for compliance with the LBAM quarantine are spelled out in Light Brown Apple Moth Regulatory Proceedures Manual (http://www.cdfa.ca.gov/phpps/PDEP/lbam/pdfs/LBAMTOC.pdf). This advisory includes information on the following subjects:

Production and retail nurseries and producers of cut flowers and greenery

- trapping and inspection
- procedures for dealing with infestations
- compliance and certification

Green waste

- compliance and certification

Community gardens

- inspection
- compliance

Harvested fruits and vegetables

- trapping and inspection
- compliance and certification

ERADICATION OR MANAGEMENT?

APHIS has called together experts from the United States, Australia, and New Zealand to form a Technical Working Group (TWG) to advise APHIS and CDFA on steps for managing the LBAM infestation in California. The TWG has recommended that the agencies adopt a long-term goal of eradicating LBAM. Because there are no single tools or methods that can be relied upon to quickly eliminate LBAM from all infested areas, the proposed eradication program will integrate a number of strategies. It was recommended that such an eradication program include the following:

- Limiting and containing the LBAM population to its present distribution
- Monitoring to appraise changes in LBAM distribution and numbers
- Reduction of higher-density populations
- Suppression of low-density LBAM populations at the edges of quarantined areas

Quarantine restrictions are aimed at limiting and containing the LBAM populations. Keeping the pest from spreading to other areas of the state is a critical element of the program, and this will be accomplished by regular monitoring with pheromone traps, inspection, treatment of infested nursery stock or other commodities, and destruction of green waste.

Eradication programs will first be focused on the most highly infested areas including agricultural crops and residential areas. When LBAM infestations are confirmed in nurseries, regulations recommend treatment with the fast-acting insecticide chlorpyrifos before plant materials can be shipped. This material is effective at destroying eggs and larvae (it kills larvae hatching from eggs but not eggs directly). Chlorpyrifos has a long residual and some fuming action that allows it to penetrate larval shelters.

More environmentally compatible control methods will be used to support eradication efforts by keeping LBAM numbers low across broader areas. Pheromone mating disruption (PMD) is currently the primary method being used in the CDFA eradication program; products may be applied either by ground or air, depending on the size of the area being treated. A number of biologically-based, reduced-risk insecticides may be used in some infested areas. These include *Bacillus thuringiensis* (Bt), spinosyns, and insect growth regulators. For example, outlying infestations are being treated with foliar sprays of Bt. Outlying infestations are defined as moth finds several miles away from other finds, and therefore are areas not likely to be naturally reinfested. The goal of treatment is to eradicate the outlying infestations before they can grow and spread. Bt also is being used to treat more heavily infested locations within areas where PMD is being applied to enhance the effectiveness of the mating disruption. Release of sterile males (SIT) and biological control are two other strategies that may become major components of the eradication or long-term management program. Successful implementation of these biologically-based tactics will require further research to adapt them for use against this pest in California.

Research on LBAM management strategies in California will be difficult under quarantine regulations. To test control techniques, researchers must have populations or laboratory colonies of a pest that the state is trying to eradicate. It is unlikely that pesticide testing, for example, would be possible in facilities established for the study of quarantine pests because of the possibility of the pesticides affecting other organisms within the facility. Unfortunately, research results from other locations such as New Zealand, Australia, and Hawaii may not be applicable to California conditions. However, some testing may be possible in locations with the highest populations of LBAM, before intensive area-wide eradication treatments begin in those areas. APHIS will be conducting insecticide trials in Australia, beginning in July.

Following recommendations of the TWG, APHIS and CDFA are formulating traditional IPM alternatives, such as applying materials effective on the life stages present, to suppress LBAM populations in areas not yet under intensive eradication, until intensive eradication can be implemented.

A Section 18 emergency exemption has been obtained for Isomate LBAM Plus and CheckMate LBAM-F for pheromone mating disruption to manage LBAM and for eradication. The exemptions have allowed for immediate use of these potentially effective, low-risk management tools in the eradication program.

If APHIS and CDFA decide LBAM can no longer be eradicated, then management of the pest will move to a traditional IPM program, which would probably include pheromone mating disruption, monitoring and use of a degree-day model to target young larvae with less-toxic materials, and biological control (possibly *Trichogramma* releases and importation of parasites from Australia).

Biology and Identification of the Pest

LBAM is a tortricid leafroller moth native to Australia. It is now established in New Zealand, New Caledonia, Great Britain, Ireland, and Hawaii. It has a broad range of plant hosts, including landscape trees, ornamental shrubs, fruit and certain vegetable crops. It is known to feed on 250 plant species in over 50 families with preference for plants in the aster (Asteraceae), legume (Fabaceae), knotweed (Polygonaceae), and rose (Rosaceae) families. LBAM has been reported as a pest on apple, pear, peach, apricot, citrus, persimmon, avocado, walnut, grape, kiwifruit, strawberry, caneberries, and cole crops. It may also infest oak, willow, poplar, cottonwood, alder, pine, eucalyptus, rose, camellia, jasmine, chrysanthemum, clover, plantain, and many other plants. In California it may encounter additional hosts it was not previously known to infest.

LBAM is found throughout Australia but it does not survive well at high temperatures and is a more serious pest in cooler areas with mild summers. The pest performs best under cool conditions (mean annual temperature of approximately 56ºF) with moderate rainfall (approximately 29 inches) and moderate-high relative humidity (approximately 70%). Hot, dry conditions may reduce populations significantly.

LBAM is capable of flying only short distances to find a suitable host. Most moths fly no further than 330 feet (100 meters), but some may fly as far as 2000 feet (600 meters). Dispersal is most likely by movement of infested nursery plants or green waste, and on equipment and containers.

DESCRIPTION

Like other tortricids, LBAM adults hold their wings over their abdomen in a bell shape when at rest and have protruding mouthparts that resemble a snout. The antennae are simple, not feather-like. The length of a resting moth is about half its wingspan. Adult size may vary during the season, with larger individuals present during cool, wet months and smaller individuals present during warm, dry months. The length of the forewing (front wing—the one on top when the moth is at rest) in the male is approximately 0.3 inch (8 mm), with a range of 0.23 to 0.4 inch (6–10 mm), and in the female the length is 0.27 to 0.5 inch (7–13 mm).

There is a considerable variation in the coloration of the wings, especially on the males (Fig. 2). The basal half (closest to the head) of the male forewing may be light brown (Fig. 2A) to pale yellow (Fig. 2D), while the distal half (farthest from the head) is reddish-brown. In strongly marked forms the distal half of the forewing may vary from reddish-brown (Fig. 2A) to blackish with purplish mottling (Fig. 1), and the basal half is sparsely speckled with black. In some males this two-tone wing coloration of the forewings may be absent. Instead, they are light brown with a slightly darker oblique marking (Fig. 2B, 2E). In the female, forewing color varies from uniform light brown, with almost no distinguishing markings or with a dark spot in the center front of the folded wings, to the typical oblique markings of the male but with less contrast between the basal and distal halves. Hind wings (back wings) of both sexes are pale brown to gray, either uniform in color or mottled with wavy dark brown markings.

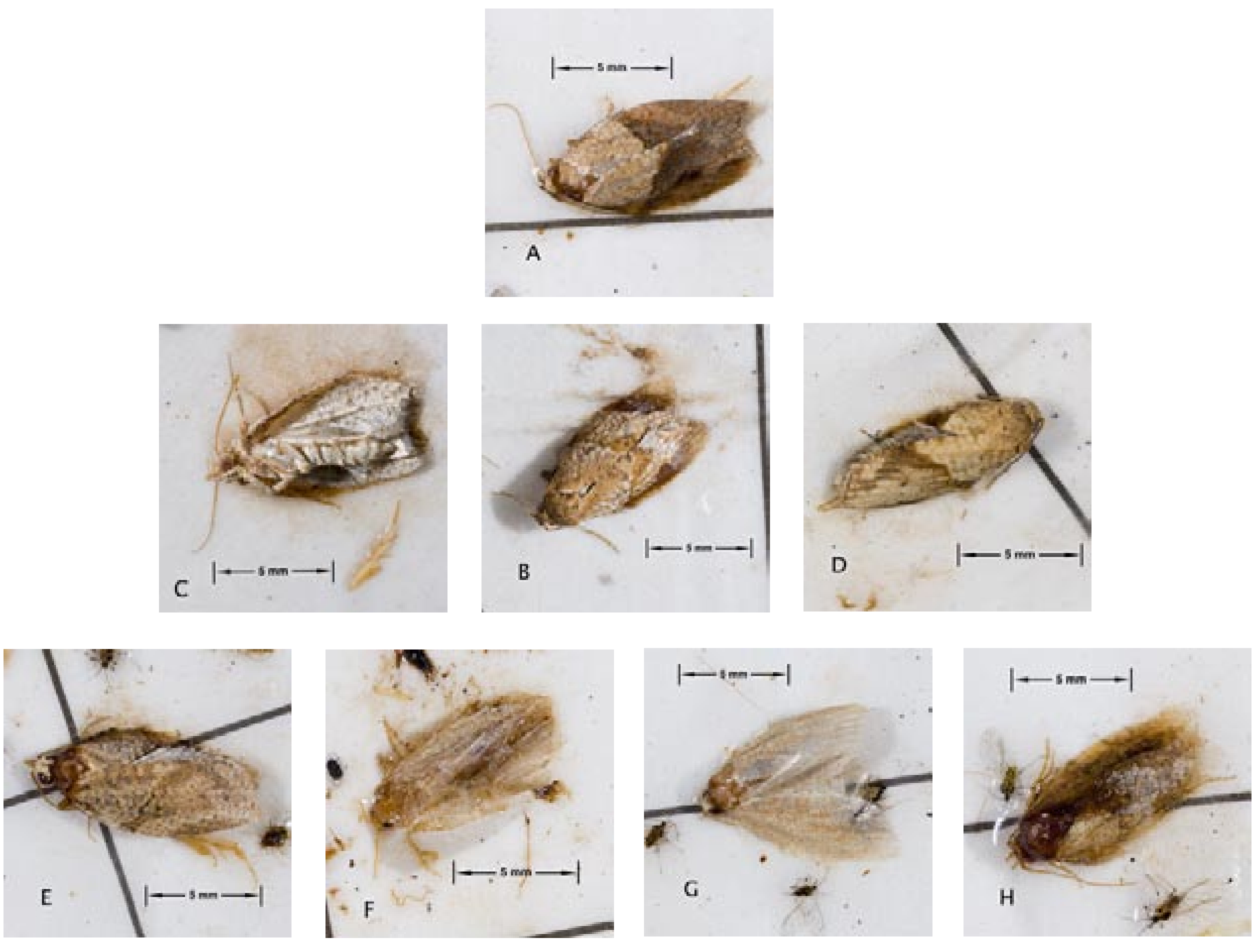

Figure 2. The wing color pattern of LBAM adults, such as those shown here in pheromone traps, can be highly variable. Photos by J. K. Clark.

Males have an extension of the outer edge of the forewing called the costal fold that runs from the base of the wing to two-fifths of the length of the wing edge (Fig. 3). This is an expanded part of the wing that folds up over the front edge of the wing as a flap. Females do not have the costal fold.

Figure 3. The costal fold along the basal two-fifths of the wing of the male LBAM helps distinguish this species from other tortricid moths. Photo by J. K. Clark.

Figure 4. Newly laid LBAM eggs are covered with a greenish, transparent coating. Photo by A. Loch, © 2007 State of New South Wales Department of Primary Industries. Used with permission of A. Loch.

The eggs are white to light green, broadly oval, flat with a pebbled surface, and are laid slightly overlapping each other. The egg mass is covered with a greenish transparent coating (Fig. 4). An egg mass may contain from 2 to 170 eggs, but typically has 20 to 50 eggs. Egg masses are deposited on the upper surface of host leaves and occasionally on fruit and young stems. As the eggs develop, they change to paler yellow-green. Immediately prior to hatching, the dark head of the developing caterpillar is visible.

The newly hatched larva is pale yellow-green, 0.06 to 0.08 inch (1.5–2 mm) long and has a dark brown head. There are 5 to 6 larval instars or stages. Mature larvae range from 0.4 to 0.7 inch (10–18 mm). The head is light yellow-brown, and the prothoracic shield (segment behind the head) is light greenish-brown with no dark markings (Fig. 5). The body is medium green with a darker green central stripe that may continue to the prothoracic shield; larvae may also have darker stripes on both sides. The hairs on the body are whitish. The thoracic legs are the same color as the head, but paler, and are also unmarked. In the anal region there is a greenish anal comb—a comb-shaped structure at the tail end of the larva. An overwintering larva may have a darker head and prothoracic shield.

The pupa is found in a thin-walled silken cocoon between two leaves webbed together. The pupa turns from green to brown as it matures (Fig. 6). It is dark reddish-brown and 0.4 to 0.6 inch (10–15 mm) long.

LIFE CYCLE

A degree-day model used for predicting LBAM development indicates that there will most likely be 2 generations a year in the central and north coast areas of California, and 3 or 4 generations a year in the Central Valley and southern California. In Australia, New Zealand, and the British Isles, generations overlap. LBAM does not have a winter resting stage (diapause). Cold winter temperatures slow larval development considerably. Thus, the pest overwinters as a second to fourth instar larva feeding on herbaceous plants, on the buds of deciduous trees or shrubs, on mummified fruit, and other plant material. Larvae may survive for up to 2 months in the winter without feeding.

Adult moths emerge after one to several weeks of pupation and mate soon after emergence. They stay sheltered in the foliage during the day, resting on the undersides of leaves. Moths fly 2 to 3 hours after sunset and before daybreak. Females begin to lay eggs 2 to 3 days after emerging, depositing eggs at night. The majority of the eggs are laid between day 6 and 10 after emergence, but females can continue to lay eggs for 21 days. Females prefer to deposit their eggs on smooth leaf surfaces. Females usually lay a total of 120 to 500 eggs, but can lay up to 1500 eggs.

Males disperse farther than females. Adults are less likely to leave areas with high-quality hosts. Adult life span is 2 to 3 weeks, with longevity influenced by host plant and temperature.

An egg takes from 5 to more than 30 days to hatch, depending on temperature, with an average of 5 to 7 days at 82ºF. The lower and upper developmental thresholds for LBAM are 45º and 88ºF, respectively. Larvae emerge from

Figure 5. Mature LBAM larva. Used with permission of D. Williams, State of Victoria Department of Primary Industries.

Figure 6. Pupa of fruittree leafroller. The pupae of all leafrollers, including LBAM, appear virtually identical. Photo by J. K. Clark.

Figure 7. All leafroller larvae use webbing to roll leaves into shelters. Photo by J. K. Clark.

eggs after 1 to 2 weeks and spread out in search of suitable feeding sites. When a larva finds a feeding site, it forms a silken shelter near the mid-rib on the underside of the leaf and begins to feed (Fig. 7). Second and later stages feed between two to several leaves webbed together, a leaf webbed to a fruit, or in the center of a cluster of fruits. The larvae feed within these shelters, and they may feed on fruit when it touches a leaf. Larvae on fruit are most likely to be found near the calyx. When disturbed they wriggle violently, suspend themselves from a silken thread, and drop to the ground where they feed on groundcover hosts. Larval development can take from 3 to 8 weeks, depending on temperature.

Pupation is completed within the shelter made from rolled-up leaves. The pupal stage lasts 1 to 3 weeks. Completion of the entire life cycle requires 620 degree-days above 45ºF.

MONITORING

An effective sex pheromone for attracting male LBAM is commercially available. It is used in delta traps to detect the presence of the moth. These pheromone traps detect and monitor the male moths and are deployed at one per 5 acres in commercial crops, with at least one in every field no matter how small.

LBAM larvae are present for most of the year, either in trees or shrubs or on herbaceous plants. To detect the eggs and larvae, examine leaves. Look for the characteristic webbing at the mid-rib vein on the underside of leaves and between leaves. At flowering, check blossom clusters for webbing and larvae. In trees they are more commonly found in the lower half and central part of the tree, closer to the trunk. In shrubs they are found mostly on the developing leaves on branch terminals. When fruit is present, examine clusters of fruit by separating and looking between the fruit. In the winter, check the ground cover and herbaceous plants for webbing. Look for larvae in fruit mummies.

DAMAGE

Like other leafroller tortricids, LBAM feeds from within the sheltering nest it constructs. Foliar feeding is usually considered minor in fruit crops, though it might be of economic importance on ornamentals. On fruit crops the primary concern is fruit damage. Larvae remove the outermost layers of the fruit surface as they feed. Superficial feeding injury to the fruit is typically caused by later immature stages. Young larvae may enter the interior of a pome fruit through the calyx. They can cause internal damage to stone fruits as well. Minor feeding damage can take the form of pinpricks or "stings" on the fruit surface. In grape, larvae can cause extensive loss of flowers or newly set berries in the spring. Later in the season, grapes can be severely damaged by larvae feeding among the berries, allowing mold organisms to enter. In citrus, larval feeding causes fruit drop or halo scars around the stem end of fruit. In crops such as kiwifruit, plum, citrus, and pome fruit, the maturing fruit produces a layer of corky tissue over the leafroller damage. Buds of deciduous host plants are vulnerable to attack in the winter and early spring.

Conifers are damaged by larval activity such as needle tying, chewing of buds, and boring into stems. In tree nurseries, damage to terminal buds on seedlings and saplings can cause multiple or crooked leaders.

IDENTIFICATION
Positive identification of LBAM can be made with certainty **only** by examining an adult.

The most efficient and reliable way of obtaining male adults is with the use of LBAM pheromone traps. The pheromone is specific for this pest and attracts males. There are many native tortricids that can be confused with LBAM. If you find a tortricid moth in a LBAM pheromone trap take it to your county agricultural commissioner's office for positive identification.

LBAM are rarely attracted to pheromone traps that target other species of leafroller. Other leafroller pheromone traps, yellow sticky cards, and McPhail traps do not effectively detect LBAM.

Suspect larvae should be delivered to the county agricultural commissioner for proper identification. Some specimens of non-LBAM larvae will have morphological characters that are never present in LBAM larvae, and can therefore be ruled out as possible LBAM. Otherwise, LBAM larvae cannot be reliably identified using morphological characters with our current knowledge. There are several reasons for this. In California there are many native tortricids, and while there is a key for identifying the adult tortricids of California, there is no comprehensive key for the larvae. There is a key of the tortricid larvae of New Zealand that includes LBAM, but it does not include native species of California and **cannot** be used to identify leafroller larvae in California. Furthermore, available descriptions of larvae are frequently made from specimens that have been preserved in alcohol, causing some characters to be lost. Lastly, the more reliable larval characters are found in the larger immature stages, but suspect LBAM larvae of all ages are being collected and submitted for identification. Work is under way to improve larval diagnostics based on morphological characters in fresh samples.

Molecular diagnostics based on PCR amplification of mitochondrial DNA were recently developed for immature specimens and are now being used to reliably identify suspected LBAM larvae. Larvae are screened using morphological characters, then DNA patterns from suspected LBAM larvae are compared to patterns of known LBAM DNA. If the patterns match, suspect larvae are considered likely LBAM. Absolute certainty is not possible because there are still many California tortricids whose DNA has not been sequenced so the reference database is incomplete. Minor genetic variation has been noted among LBAM specimens, but it is not yet known whether this is normal population variation or an indication of multiple introductions.

HOW TO SEND A SAMPLE FOR IDENTIFICATION
Suspected LBAM larvae should be brought **alive** to the county agricultural commissioner's office. If possible, bring the live larvae inside the webbed nests of rolled-up leaves, flowers, or fruit clusters. For viewing larval morphological characters, the specimen has to be a late instar and must have been properly preserved by experts. County agricultural commissioners offices have the equipment and expertise to do this. Moths caught in pheromone traps should be submitted still in the traps. Specific procedures for submitting samples are spelled out in the Light Brown Apple Moth Regulatory Procedures Manual (http://www.cdfa.ca.gov/phpps/PDEP/lbam/pdfs/LBAMTOC.pdf).

Potential IPM Alternatives

The current long-term goal is to eradicate LBAM from California. However, no single control technique currently exists that can be practically, safely, and effectively implemented over the entire LBAM-infested area. Because of this, current recommendations to successfully eradicate LBAM are multi-phase in nature.

Eradication efforts using available technologies (e.g., pheromone mating disruption) will focus initially on specific localities such as extremely infested areas. If initial eradication attempts are successful and deemed feasible for expansion, then additional LBAM infestations will be eradicated as quickly as conditions, technology, logistics, and fiscal support permit. While eradication attempts are under way, it is important that LBAM infestations throughout the infested range do not continue to increase in size and expand to uninfested areas such as the Central Valley and southern California. Pest management tactics that rely on more environmentally compatible methods are desirable to support the eradication effort by keeping LBAM at low numbers across agricultural, urban, and natural areas.

Fortunately, the biology and ecology of LBAM make it susceptible to a variety of potential control methods that are less environmentally harmful and more socially acceptable than highly toxic, broad-spectrum insecticides such as chlorpyrifos. However, these alternatives do not generally act as quickly (i.e., less than 72 hours) as the insecticides they replace (organophosphates, carbamates, pyrethroids). Some alternative controls developed in Australia and New Zealand, such as pheromone mating disruption, will have to be modified for California conditions while others (e.g., sterile insect technique, augmentative biological control) will require various levels of development, experimentation, and validation to make them functional and effective.

Lastly, the effectiveness of these alternative controls may be influenced by the manner in which they are implemented. Mating disruption and sterile insect release will be more successful when applied over large areas (e.g., square miles). Classical biological control is an area-wide management tactic. Also, these large-scale approaches generally require government support for successful development and implementation. In contrast, reduced-risk chemicals, insect pathogens or their by-products (e.g., *Bacillus thuringiensis* ssp. *kurstaki*), and augmentative releases of natural enemies (e.g., *Trichogramma* egg parasitoids) can be effective on a small scale, such as acres, and implemented with minimal effort. Discussion of the availability and effectiveness of these management approaches follows.

SMALL-SCALE APPROACHES

Reduced-Risk Pesticides. These compounds offer an alternative to organophosphate, carbamate, and pyrethroid insecticides that are potentially a human health risk, an environmental threat, or highly disruptive to beneficial species such as bees or biological control agents. Some may meet requirements for organic production. Only those compounds that have shown good effectiveness against LBAM in Australia and New Zealand are discussed below. Because timing spray applications to target susceptible life stages is highly important for control, the validation and adaptation of a LBAM phenology model under California conditions will be important for predicting generation cycles.

Insect growth regulators (IGRs). This group of compounds is derived from naturally occurring hormones that insects use to trigger molting events during their development from egg to adult. Thus, they work only on the immature stages. These compounds may be applied to the foliage, and timing of applications is important to contact the susceptible life stages. Tebufenozide is active against larvae and may be applied to crops using the formulation Confirm 2F; a formulation for ornamentals is pending registration. Methoxyfenozide (Intrepid 2F) is active against both eggs and larvae, but is registered for use only on some crops. For methoxyfenozide to be effective on eggs, they must contact the chemical residue as they are laid. Because leafroller eggs are laid in overlapping layers, not all eggs will contact the chemical, so control of eggs is not complete. Care must be taken when using this product around bodies of water where runoff may impact aquatic invertebrates.

Spinosad. This insecticide is produced by a fermentation process using the microorganism *Actinomycetes spinosa*. It is applied as a foliar spray at low field rates, targets only larvae, and is most effective when eaten by the larvae. It is available under various trade names including Success and Entrust (organic formulation) for crops and Conserve for nursery, ornamental, and greenhouse plants. Although generally safe for predators, it may impact hymenopteran parasitoids (wasps) that are useful biological control agents.

Insect pathogens. Commercially available insect pathogens for LBAM suppression are limited to *Bacillus thuringiensis* ssp. *kurstaki* (Bt). This product is effective only on larvae. The formulation is mixed with water and applied to infested plants. The Bt residue must be eaten by the larvae; contact alone will not kill LBAM larvae. Because Bt must be ingested, the leaf-rolling or leaf-tying behavior of the insect may help protect the larva from this material. Bt is most effective on young larvae. Nuclear polyhedrosis virus (NPV) that infects LBAM does exist, but it is not commercially available. Development is necessary to improve the mass production methods for the NPV. Codling moth granulosis virus does not appear to be effective against LBAM.

Augmentative Biological Control. This approach relies on the use of beneficial insects (predators or parasitoids) that are typically mass produced and released in the infested areas at rates that vary from hundreds to millions of individuals per acre. Predators attack and quickly devour their prey either by eating the pest (e.g., ladybugs) or sucking out the body liquids (e.g., lacewings). Parasitoids (or parasites) are insects that deposit their eggs inside the body or on the surface of their host insect, and the hatched immature insect feeds on the host to complete its development to the adult stage. Parasitoids do not immediately kill their host; death may require several days or more. Many effective parasitoids are tiny wasps that can barely be seen by the unaided eye. *Trichogramma* wasps are some of the smallest insects known, and they attack the egg stage of their hosts. Augmentative releases may be made in conjunction with the use of reduced-risk insecticides if timed correctly.

Predators. Presently, no information is available on using mass-reared predators for LBAM suppression.

Parasitoids. The only parasitoids that may be useful are the *Trichogramma* egg parasitoids. These biological control agents parasitize the eggs of their host insects and the *Trichogramma* larvae complete their entire developmental cycle (egg to adult) within the host egg. *Trichogramma carverae* is used in augmentative releases in some crop systems in Australia, but is not present in the U.S. Various *Trichogramma* species are commercially available in the U.S., but their effectiveness in suppressing LBAM is unknown. Although *Trichogramma* appear to have a wide preference for the various moth species they attack, their searching behavior for eggs may better define which species are attacked. Some *Trichogramma* prefer to search for eggs in tree canopies while others prefer plants that are low to the ground. No guidelines are available for *Trichogramma* use in inundative releases against LBAM in California. Research is needed to determine the preference of the wasps for LBAM eggs, the numbers of wasps required to effectively suppress LBAM in a locality, the optimal timing of releases, and the types of crops (e.g., vegetable crops, vineyard, orchard, nursery, etc.) in which releases would be effective.

AREA-WIDE APPROACHES

These approaches may be beyond the scope of individual growers or groups and usually need significant financial and logistic support to be successful. They typically have large-scale government and private industry involvement.

Pheromone Mating Disruption. Female moths commonly emit chemicals known as pheromones to attract males to them for mating. Many pheromones have been chemically analyzed and can be synthetically produced. Some pheromones are highly specific, attracting only one species, and others are more general in nature, attracting more than one insect species. Pheromone specificity is gained by varying mixtures of the chemical components. LBAM pheromone has two key components. **Both components must be present** for the material to be highly attractive to LBAM males and effective as a mating disruption tool. Man-made pheromones are used with traps to monitor moth activity, for trapping moths for control, and for interfering with the ability of male moths to locate females for mating. As greater numbers of females go unmated within an area, fewer fertilized eggs will be laid to produce a new generation of offspring. Mating can be disrupted by saturating the air with large quantities of pheromone, thereby interfering with the ability of males to follow aerial scent trails to emitting females.

Many factors influence the success and cost of mating disruption. These include access to enough pheromone to saturate targeted areas; a practical and inexpensive method to dispense pheromone over long periods such as weeks or months; correct timing of the pheromone release; the inability of affected males to locate females within the treated area; low densities of the target pest; and low wind speeds.

Mating disruption is commonly used in California fruit orchards for peach twig borer, oriental fruit moth, and codling moth. Mating disruption has not worked well with various leafroller species. However, in Australia LBAM has been managed in citrus, grapes, and other crop systems using mating disruption. Mating disruption currently is the primary tool being used by the CDFA for the eradication effort in California. Novel strategies to employ synthetic pheromones for LBAM suppression are being investigated in Australia and New Zealand, and these may be available in the future for California.

Sterile Insect Release. Sterile insect release (SIT) is commonly used to eradicate Mediterranean fruit fly (Medfly) infestations in California. Basically, millions of Medfly individuals are reared in colonies and irradiated to make them sterile. These are then released in areas where Medfly infestations have been found, and sterile males mate with wild females and prevent the females from laying viable eggs. This technique may hold promise for LBAM if mass rearing systems can be developed to produce the needed numbers of LBAM males to sterilize for release. These studies are currently under way.

Classical Biological Control. This tactic is commonly employed when

- An invasive species has established in a new location.
- It is extremely difficult or expensive to control due to various factors (e.g., high levels of pesticide resistance, significant economic damage to low-value crops or natural ecosystems, large plant host range and presence in unmanaged land, or pesticides are ineffective because of the organism's biology).
- Effective natural enemies exist in other locations where the organism is found in low numbers.

If these criteria are met, natural enemies may be collected in the former home of the invasive species and imported to the new location and released to control the invasive species. Highly successful biological control introductions can lead to complete control of the target pest such that the pest no longer causes economic injury. Although the target pest may be reduced to very low numbers, it will not be eradicated from the area. Additionally, imported natural enemies may impact organisms that are not the intended target. Because of this, natural enemies that may be considered for a classical biological control program must undergo tests, which may take several years, to determine whether they attack more than one insect species. If the candidate natural enemy does not target a very limited range of hosts or prey, there is a lesser chance that it will be approved for release in the new location.

In Australia, as many as 25 different parasitoid species have been reared from LBAM collected in the field. However, there apparently are no "silver bullet" species that are well recognized for suppressing LBAM populations across a wide variety of crops. Because of this, the success of a classical biological control program may be doubtful if eradication is the goal. The resources that would be directed towards a classical biological control program would probably be better used in developing and refining effective eradication techniques.

One advantage in California is that there are numerous leafroller species established within the state and many of these have effective parasitoids (e.g., *Cotesia, Exochus*, *Macrocentrus*, *Nemorilla*, *Trichogramma*) and predators (spiders, minute pirate bug, lacewings, *Phytocoris* bugs), including some in the same genera (e.g., *Exochus*) as those found in Australia. It is highly probable that some of the California native predators will expand their prey ranges to include LBAM eggs, larvae, and pupae. However, this may require a few years to occur, given the time required for these natural enemies to discover and exploit LBAM infestations across the range of potential habitats (urban, natural, agricultural).

Pesticides for Controlling LBAM

Listed below are examples of regulated products for control or prevention of LBAM at nurseries and crop production areas. Establishments where LBAM infestation has been detected must follow procedures outlined in the Light Brown Apple Moth Regulatory Manual. **(Check the CDFA LBAM Web site frequently for updates.)** Users must follow all label restrictions. Many active ingredients are in multiple products, each with specific site recommendations. If your crop (site) does not appear, alternative products may be available for your situation. Search products based on multiple categores (site and chemical code) at www.cdpr.ca.gov/docs/label/m4.htm.

Table 1. LBAM Regulated Treatments for Nurseries and Host Crops
Source: California Department of Food and Agriculture (June 25, 2007)

Active Ingredient	Product	Sites	Target Life Stage	EPA Reg No
BT	Crymax Lepinox Dipel DF Pro Dipel DF	Ornamentals & crops Ornamental Organic Crops Organic	Larvae	70051-86 70051-89 73049-39 73049-39
Carbaryl	Sevin 4F	Ornamentals & crops	Adults [1]	264-349-ZB
Carbaryl	Sevin SL	Ornamentals & crops	Adults[1]	432-1227-ZA
Carbaryl	Sevin Brand 80S	Crops	Adults[1]	264-316-ZC
Chlorpyrifos	DuraGuard ME Chlorpyrifos Pro 2 Chlorpyrifos Pro 4 Chlorpyrifos 4E AG Dursban 2.5G Durban 4E[3] Dursban 50W Dursban Pro Prentox Dursban 4E	Ornamentals & greenhouses Ornamentals Greenhouses	Eggs[2]	499-367-ZA 51036-152-AA 51036-154-AA 66222-19-AA 62719-276-AA 62719-11-AA 62719-72-AA 62719-166-ZA 655-499-AA
Deltamethrin	Suspend SC	Ornamentals	Adults	432-763-ZB
Dimethoate	Clean Crop Dimethoate 400	Ornamentals & crops		34704-207-AA
Lambda-cyhalothrin	Warrior with Zeon	Crops	Larvae	100-1112-AA
Methoxyfenozide	Intrepid 2F	Crops	Larvae[4]	62719-442-AA
Phosmet	Imidan 70 W Imidan 70WP	Ornamentals Crops	Eggs, larvae	10163-169-ZA 10163-169-AA
Spinosad	Conserve Entrust	Ornamentals Crops	Larvae	62719-291 62719-282
Tebufenozide	Confirm 2F	Ornamentals & crops	Larvae	62719-420

Footnotes added by University of California authors. More information on use of these pesticides can be found in the pesticide treatment tables for leafrollers in various crops in the *UC IPM Pest Management Guidelines* at http://www.ipm.ucdavis.edu/PMG/ or by searching the UC IPM Web site for the active ingredients.

[1] Carbaryl is active against leafroller larvae.

[2] Kills first instar larvae as they chew through their egg shells when hatching. Also kills older larvae and adults. These chlorpyrifos products are registered for use on LBAM host crops:
Lorsban 50W (62719-39-AA), Lorsban-4E (62719-220-ZA), Lorsban-75WG (62719-301-AA), Lorsban 15G (5481-525-AA).

[3] Dursban 4E under review at EPA for cancellation.

[4] Does not control eggs completely because the overlapping nature of the eggs prevents contact of the pesticide with all the eggs in an egg mass.

MITIGATING MEASURES TO REDUCE THE IMPACT OF PESTICIDES ON THE ENVIRONMENT
Several of the insecticides available for LBAM management, including spinosad, *Bacillus thuringiensis* ssp. *kurstaki*, and the IGR methoxyfenozide (Intrepid), have minimal negative impacts on human health and the environment, including water quality. The mating disruption technology that has been implemented for this pest is also an environmentally sound approach.

Chlorpyrifos (Lorsban, Dursban)is labeled for use on ornamental nursery stock in nurseries in California. Chlorpyrifos is an option for treating nursery stock in nurseries where LBAM immature life stages have been found. Chlorpyrifos controls all stages of the pest including hatching eggs and has a longer residual than the reduced-risk products mentioned above. Chlorpyrifos must be used with care because of its potential for contaminating surface water. This material is **not** being used for eradications in urban areas.

If using a broad-spectrum pesticide (organophosphate, pyrethroid, carbamate), consider management practices that reduce pesticide movement off-site and protect other sensitive areas:

- Identify and take special care to protect sensitive areas, for example waterways, riparian areas, or residential or school buildings, near your site.
- Choose sprayers and application procedures that keep pesticides on target.
- Install an irrigation recirculation or storage and reuse system.
- Use drip rather than sprinkler or flood irrigation.
- If using overhead irrigation, do not irrigate pesticide-treated foliage until treated foliage dries.
- Limit irrigation to amount required using soil moisture monitoring and evapotranspiration measurements.
- Use pulsed irrigation—several shorter irrigation runs rather than one long run to allow soil to absorb water between runs.
- Consider vegetative filter strips or ditches.
- Redesign inlets into tailwater ditches to reduce erosion. Ditches should not be lower than furrows.

Impacts on Specific Industries and Situations

The quarantine requirements for LBAM will be updated regularly by the CDFA. For the latest information, check the CDFA LBAM Web site listed below.

CURRENT IMPACT ON NURSERIES AND ORNAMENTALS
The majority of LBAM detections on agricultural lands in the infested areas have been in production and retail nurseries located near urban areas, and therefore these nurseries are heavily impacted by LBAM quarantine regulations. Since nursery stock is often grown in one location and shipped or moved to distant locations, it is easy for LBAM and other pests to be moved along with the nursery stock. In addition, green waste such as vegetative clippings, leaf litter, or propagative materials might harbor LBAM and be moved inadvertently off-site.

Retail nursery operators may have a particularly complicated set of burdens and associated decisions to make with a LBAM infestation. Often retail nurseries do not possess the spray equipment necessary for widespread application of a pesticide as would be required by a quarantine-mandated pesticide application. In that case, a private pest control company might have to be hired to make the pesticide application. Retail nurseries must be closed for business during the pesticide application, the restricted entry period, and until reinspected and found free of LBAM. In addition, retail nurseries usually have a very wide range of edible and ornamental material further complicating the selection of a registered pesticide.

Quarantine Requirements. All nursery operations within quarantined counties must follow quarantine requirements. Current maps of quarantined areas can be found on the CDFA LBAM Web site (http://www.cdfa.ca.gov/phpps/PDEP/lbam/lbam_main.html). Nursery material affected by the quarantines includes:

- Production and retail nursery stock, cut flowers, garlands, wreaths, greenery of any plants
- Garlands, wreaths, greenery, and cut Christmas trees
- All green waste

Details of current quarantine requirements for trapping, inspection, treatment of infestations, and certification are spelled out in Light Brown Apple Moth Regulatory Proceedures Manual, available on the CDFA LBAM Web site (http://www.cdfa.ca.gov/phpps/PDEP/lbam/pdfs/LBAMTOC.pdf). **Check the Web site frequently for updates.** A summary of the current requirements is given here; because quarantine requirements may be modified, check the CDFA site for updated information or talk with your county agricultural commissioner's office.

If possible, incoming shipments, especially from known LBAM-infested areas, should be isolated in a quarantine area away from production and inspected and possibly treated prior to moving them into the production area.

Inspection and Treatment Recommendations. Inspect nurseries every 3 days or at least twice per week. Randomly check 10 to 50 plants per variety for the green leaf-rolling caterpillar. Look for webbed young leaves and white to pale green overlapping masses of LBAM eggs on the upper surface of leaves. Check leaves at branch terminals in particular. The preferred egg-laying sites are the leaves, especially young leaves, although eggs can occasionally be found on fruit and tender young stems. Larvae construct silken shelters on the underside of leaves. Older larvae roll together leaves and buds; look for rolled leaves held together with webbing. Young larvae are tiny and are often difficult to see. Look for webbing in leaves hiding green caterpillars.

If you find eggs or larvae that you suspect are LBAM, place the **live** specimens in a vial or small jar and send them to your county agricultural commissioner's office for identification. There are many species of leaf-rolling moths in the area, and they are very similar in size and appearance. The Light Brown Apple Moth Regulatory Procedures manual has instructions for how to prepare specimens and submit them for identification.

If any of the collected specimens are confirmed to be LBAM, all plants in the nursery are subject to quarantine action, which may include treatment, a holding period, and re-inspection. Quarantine action must take place before plants can be shipped from the infested nursery. Chlorpyrifos has been determined to have efficacy against eggs and larvae. Treatment with chlorpyriphos may be selected as the quarantine action by growers wishing to move their plants from the nursery as soon as possible.

After the expiration of the restricted entry interval, the nursery must be inspected by the local agricultural commissioner. If the inspection is negative for LBAM, the nursery can adopt its usual integrated pest management program.

However, if LBAM larvae are found during the re-inspection, a second treatment of the plants where the larvae were found must be made until a negative result is attained. Furthermore, after the last treatment that yields negative LBAM, another re-inspection of the nursery will be made as determined by the agricultural commissioner and CDFA.

A table listing states requesting pre-shipment notification of nursery stock from quarantined areas can be found on the CDFA Web site: (http://www.cdfa.ca.gov/phpps/PDEP/lbam/pdfs/LBAM_PreshipmentNotification.pdf)

If growers within or near a quarantine county wish to proactively spray their commodities, CDFA has prepared a list of treatments (Table 1).

POSSIBLE IMPACT ON VEGETABLES

The only significant leafroller pest of vegetable crops in California is omnivorous leafroller on peppers. LBAM attacks a number of vegetables such as broad bean, carrot, cole crops, parsley, pepper, potato, sweet pea, and tomato. Although it is impossible to predict how LBAM will affect California vegetable-growing systems, in Australia LBAM is only a minor pest of vegetable crops.

The best strategy for growers and pest control advisors is to follow the procedures for sampling caterpillars on vegetables found in the *UC IPM Pest Management Guidelines* (http://www.ipm.ucdavis.edu/PMG/). Check for signs of leafroller activity when monitoring fields. Look for leafroller egg masses, webbed leaves, and leaves webbed against fruit surfaces.

Materials available to control leafrollers and other caterpillar pests on vegetable crops are also effective on LBAM. In quarantine zones, treatments may be warranted to prevent the presence of leafrollers in harvested vegetables. Formulations of *Bacillus thuringiensis* ssp. *kurstaki* and spinosad are available for organic vegetable growers. Control weeds in and around fields to reduce survival and overwintering of leafroller larvae.

If a suspected caterpillar is found, collect it and webbed leaves and take the sample to the local agricultural commissioner. For information about chemical treatments for a vegetable field suspected to be infested by LBAM, contact the local UC Cooperative Extension Office or the local agricultural commissioner.

POSSIBLE IMPACT ON STRAWBERRIES

Strawberry fruit are not considered to be preferred host material for LBAM, and current California production practices already use measures that are effective at suppressing LBAM. However, there is potential to confuse larvae of endemic leafrollers with LBAM larvae. The species that occurs most commonly is garden tortrix. Others are apple pandemis, orange tortrix, omnivorous leafroller, and strawberry leafroller. These leafrollers have life cycles and feeding patterns similar to each other and to LBAM. Their primary damage occurs when they feed on the surface of fruit.

Begin a monitoring program by examining leaves for leafroller egg masses and larvae, especially the characteristic webbing together of leaf surfaces. Destroy any fruit showing evidence of larval feeding. Because it is difficult to distinguish larvae of LBAM from endemic leafroller species, special care should be taken to keep all leafrollers from contaminating fruit, baskets, or boxes, and to keep any leaves or other materials that might harbor leafrollers out of the pack.

Several chemicals registered for use on strawberries for endemic leafrollers and other caterpillar pests are named as controls for LBAM in Australian studies. These include *Bacillus thuringiensis* ssp. *kurstaki* (various formulations of Bt), spinosad (Entrust and Success), methoxyfenozide (Intrepid), bifenthrin (Brigade), and methomyl (Lannate). Organic growers can use approved formulations of Bt and spinosad. However, additional care may be needed to prevent infestations of LBAM in organic production fields because other insect pests are not being managed with conventional products that would incidentally control LBAM.

Second-year production fields should be closely monitored and plowed under if abandoned during the season to prevent them from becoming a potential source of LBAM infestations. Controlling weeds and removing trash in and around strawberry fields helps reduce survival and overwintering of leafrollers. For more information on managing leafrollers in strawberries, see the *UC IPM Pest Management Guidelines: Strawberry* at http://www.ipm.ucdavis.edu/PMG/.

If a suspected caterpillar is found, collect it and any webbed leaves or fruit where it is feeding and take the sample to the local agricultural commissioner.

POSSIBLE IMPACT ON CANEBERRIES

Several leafrollers, including apple pandemis, omnivorous leafroller, and orange tortrix, are pests in California caneberries. They are especially common in blackberries. Although it is impossible to predict, LBAM is likely to become a significant pest of these crops if it becomes established in California. Management of leafrollers in quarantine zones is aimed at preventing any leafrollers in harvested berries.

Monitor caneberries for any leafroller infestation by looking for evidence of egg masses, larvae, pupae, pupal cases, webbing, and feeding damage regularly during the season. Destroy fruit with signs of larval feeding.

Materials registered for leafroller control in caneberries will also control LBAM. Formulations of *Bacillus thuringiensis* ssp. *kurstaki* and spinosad are available for organic growers. All pesticide applications will be more effective when targeted at the early instars of the larvae. Because generations can overlap, it may be useful for growers to repeat applications if evidence of tortricids continues to be found during the season.

Proper field management of caneberry crops can also substantially reduce risk of LBAM infestation. Most overwintering tortricid larvae survive in surrounding weeds or in trash on and beneath the canes, so these should be removed or disced into the ground. For more information on managing leafrollers in caneberries, see the *UC IPM Pest Management Guidelines: Caneberries (*http://www.ipm.ucdavis.edu/PMG/).

If you find eggs or larvae that you suspect might be LBAM, contact the local local agricultural commissioner.

POSSIBLE IMPACT ON VINEYARDS

Presently in California two tortricid leafrollers may appear as pests in vineyards. Orange tortrix is common in coastal vineyards, and the omnivorous leafroller is found in hot inland valleys, but may also be present in warmer coastal areas. If established, LBAM would probably cause damage similar to that of these two leafrollers. In its native range, LBAM does not do well at high temperatures but thrives in cooler areas with mild summers. Depending on the climatic conditions, LBAM may have from 2 to 4 generations a year.

As with other leafrollers, feeding damage to the buds may occasionally be caused by the overwintering larvae. In the spring, feeding on developing bunches may cause extensive loss of flowers or newly set berries. In the summer, damage is caused by LBAM larvae entering bunches and feeding along the bunch stem and on the berries. Damage to developing and ripening bunches can increase the incidence of Botrytis bunch rot.

As with other leafroller pests on grapevines (see *UC IPM Pest Management Guidelines: Grape* at http://www.ipm.ucdavis.edu/PMG/), there are a number of control strategies available for LBAM management. An important method for reducing overwintering populations is to remove broadleaf weeds and cluster mummies when pruning, then place them in row middles and disc them into the ground.

The effect of natural enemies on LBAM in California is presently unknown. Leafrollers are controlled by several predators such as lacewings, spiders, minute pirate bugs, damsel bugs, and bigeyed bugs, and by several parasitic wasps. Since predators are generalists, they will feed on LBAM. Studies will be needed to determine if the parasitoids that attack native leafrollers may shift to parasitize LBAM.

If insecticide treatment is necessary, then applications can be timed by monitoring flights with pheromone traps, tracking seasonal development with a degree-day model, and field monitoring. There are several reduced-risk insecticides available for control of LBAM. Spraying is most effective after eggs have hatched, but before caterpillars build feeding shelters. It is important to control larvae early in the season before bunch closure. Insect growth regulators are registered for the control of leafrollers in grapevines. *Bacillus thuringiensi*s and a formulation of spinosad are approved for use on organically certified grapes.

If a suspected LBAM caterpillar is found, collect it and the webbed leaves or fruit where it is feeding and take the sample to the local agricultural commissioner.

If LBAM becomes established in California, production costs will increase due to additional monitoring (traps and scouting) needed for this pest and control measures in those regions where climate conditions favor LBAM.

POSSIBLE IMPACT ON TREE CROPS

Stone Fruits. Stone fruits in California are attacked by a variety of leafroller species including the fruittree leafroller, obliquebanded leafroller, and omnivorous leafroller. LBAM is damaging to stone fruits grown in warmer areas of Australia, but it cannot be predicted how serious it may become on stone fruits in California. Because many of California's stone fruits already must meet international shipping standards, LBAM is not likely to add significant hardships to growers who presently manage the other leafrollers and species such as the oriental fruit moth and peach twig borer in their orchards.

Parasitoids such as *Macrocentrus* spp., *Cotesia* (*Apanteles*) spp., and *Exochus* spp. commonly attack leafroller larvae, and predators such as lacewings, assassin bugs, minute pirate bugs attack the eggs and larvae. The presence of LBAM in orchards will probably provide an additional food source for these natural enemies.

Follow the monitoring recommendations for leafrollers in the *UC IPM Pest Management Guidelines* for stone fruits. Monitoring for leafroller activity in early spring is very important because many available control materials are most effective on young larvae.

Management programs are already in place for the common leafrollers, and the recommended reduced-risk insecticides (e.g., spinosad, insect growth regulators, and Bt) are also recommended for LBAM suppression. Application of chlorpyrifos is limited to dormant and delayed-dormant periods in stone fruit crops, and other alternatives are available (narrow range oil, esfenvalerate) that may have lesser environmental impacts than chlorpyrifos. For more information on managing leafrollers in stone fruits, see the *UC IPM Pest Management Guidelines* at http://www.ipm.ucdavis.edu/PMG/ for stone fruit crops.

If a suspected LBAM caterpillar is found, collect it and the webbed leaves or fruit where it is feeding and take the sample to the local agricultural commissioner.

Pome Fruits. Pome fruits are attacked by several types of leafrollers including fruittree leafroller, obliquebanded leafroller, apple pandemis, and orange tortrix. As its name implies, LBAM is an important pest of apples and pears. The primary concern is the trade restrictions imposed by importing countries. If LBAM is found in pome fruit-producing counties, the inability to export fruit to some countries may cause severe economic hardship to the industry. Also, feeding damage to the fruit may reach economic levels.

Leafroller larvae cause superficial injury to the fruit surface and may cause extensive damage when feeding in between the fruit in a cluster. Sometimes the larvae burrow into the fruit around the stem. Small larvae may enter the fruit through the calyx or cause “stings” on the fruit surface.

Follow the monitoring procedures for leafrollers given in the *UC IPM Pest Management Guidelines* for apple and pear. Watch for leafroller egg masses and signs of leafroller activity when monitoring orchards. Look for leaves webbed together and leaves webbed against fruit.

The management of LBAM is similar to the control of other leafrollers of pome fruit (see *UC IPM Pest Management Guidelines* for apples and for pears at http://www.ipm.ucdavis.edu/PMG/). Sanitation includes removal of winter weeds and thinning of fruit. If insecticide treatment is necessary, several reduced-risk insecticides are available for control of LBAM. Good early-season control is essential.

If a suspected LBAM caterpillar is found, collect it and the webbed leaves or fruit where it is feeding and take the sample to the local agricultural commissioner.

Citrus and Avocado. Citrus crops in California are attacked by a number of leafroller pests (fruittree leafroller, Amorbia, omnivorous leafroller, orange tortrix). Amorbia (western avocado leafroller) is the main leafroller pest of avocado, with orange tortix being a minor pest in coastal areas. Leafrollers usually are minor or sporadic pests in citrus and avocado because parasites keep their populations below damaging levels. LBAM is damaging to citrus grown in Australia and is a minor pest of avocado in New Zealand. Although it cannot be predicted how serious it may become on citrus and avocado in California, it is likely to be a minor pest as long as natural enemies aren’t severely disrupted by broad-spectrum pesticides. However, if LBAM were found in citrus and avocado growing areas of California, quarantine restrictions, if enacted, would have a serious economic impact on exports.

Impact on citrus is likely to be similar to damage from Amorbia, which feeds in the spring on new flush, newly set fruit, or on ripening Valencias. Early in spring, young larvae feed mostly on new growth flushes, often resulting in curled leaf terminals. Damage to young fruit occurs when the larvae web and feed under the calyx end of the fruit causing a ring scar similar to citrus thrips. Damage to maturing fruit occurs when larvae tie leaves to the fruit, feeding on the rind and sometimes boring inside. This injury provides entry sites for secondary decay organisms, and fruit will drop within 1 to 2 weeks. Fruittree leafroller is primarily a pest when it attacks older fruit, including ripening Valencias, navels, and grapefruit. Whether LBAM in California would become a pest of older fruit is unknown.

Impact on avocado also is likely to be similar to damage from Amorbia. Economic damage occurs primarily when larvae web leaves to fruit or feed among fruit touching in a cluster. Larvae feed on fruit skin, causing a scarring that results in downgrading or culling of fruit.

Look for LBAM under the sepals at the calyx end of young citrus fruit, under leaves webbed against maturing fruit, and where avocado fruit touch in clusters. Monitoring recommendations for Amorbia in the *UC IPM Pest Management Guidelines* for citrus and avocado may be useful. Monitor for signs of larval activity throughout the year because LBAM larvae remain active during the winter.

Parasitoids such as *Macrocentrus* spp., *Cotesia (Apanteles)* spp., and *Exochus* spp. commonly attack leafroller larvae, and predators such as spiders, lacewings, assassin bugs, and minute pirate bugs attack the eggs and larvae. The presence of LBAM in citrus and avocado orchards will probably provide an additional food source for these natural enemies.Management programs are already in place for the common leafrollers, and the reduced-risk insecticides (e.g., spinosad and Bt) recommended for their control are also recommended for LBAM suppression. In avocado, Bt applications may be effective on young larvae. In citrus, Bt may be applied before petal fall. At or after petal fall, a tank mix of spinosad plus either chlorpyrifos or a pyrethroid could be used to control LBAM; for more information see the *UC IPM Pest Management Guidelines* for citrus and avocado at http://www.ipm.ucdavis.edu/PMG/.

Nut Crops. Several leafroller species occur in the nut-producing areas of California, but do not cause significant damage to these crops. It is not anticipated that LBAM would become a significant pest. Because leafrollers are not found in or on nuts after they are harvested, hulled, and dried, LBAM is not a quarantine concern for these crops.

POSSIBLE IMPACT ON RESIDENTIAL AREAS

LBAM was first detected in California in a residential neighborhood. Quarantine and eradication efforts include residential areas in all the affected counties.

Detection. The primary method of detecting LBAM is pheromone traps put out by CDFA and the county agricultural commissioners and checked regularly by state biologists. Residents and businesses may be asked to allow one to be placed on their property.

If LBAM is found in a neighborhood, the area will be put under a quarantine by CDFA, which means that no one can move affected plants, vegetables, flowers or fruit from the quarantined area and must follow other local restrictions. In addition, community gardens within the quarantine area must be issued a compliance agreement from their county agricultural commissioner that allows movement of produce out of the garden, and all green waste from gardens must be disposed of through the local municipal green waste services to be sure of proper destruction.

If LBAM is found, CDFA and the county agricultural commissioner may make an eradication treatment with an insecticide. Currently an organic formulation of *Bacillus thuringiensis* (Bt) is being used for residential treatments. This material has low toxicity to humans and wildlife and is safe for the environment.

If you find a moth or caterpillar that resembles LBAM in your garden, take it to your county agricultural commissioner's office for identification or call the CDFA Pest Hot Line at (800) 491-1899. Many other common leafrollers resemble LBAM and it is difficult to distinguish among them.

Controlling LBAM in Your Garden. Currently, monitoring and control of LBAM in all locations is being done by CDFA and the county agricultural commissioners.

Although LBAM attacks many types of plants, it is not likely to cause serious damage to them in backyard situations. In many cases, treatment would not be needed in backyards, except to limit spread of this pest to commercial agriculture where the impact could be very serious. However, where LBAM is causing significant damage, it can be controlled effectively with several low-toxicity home-use insecticides, including *Bacillus thuringiensis* and spinosad. These materials must be applied to the larval (caterpillar) stage of the insect and repeat applications may be necessary. Good coverage of all plant surfaces is necessary for effective control.

For more information, check with the county agricultural commissioner for local restrictions. Also see the CDFA

LBAM Web page (http://www.cdfa.ca.gov/phpps/PDEP/lbam/lbam_main.html) for regularly updated maps of new infestations. Regulatory requirements for community gardens in quarantined areas are spelled out in the Light Brown Apple Moth Regulatory Procedures Manual available on the Web page.

AGRICULTURE–URBAN INTERFACE

People living close to agricultural operations should be aware that there may be occasions when nearby growers will be applying pesticides more often than usual. This is likely to be a short-term occurrence and is necessary in order to meet regulatory requirements and contain the spread of a pest that can cause great damage to California's economy.

Where agricultural operations are close to homes, schools, or other nonagricultural situations, growers should consider using less-toxic materials (as allowed by regulations), larger droplet size, or a spray additive to reduce drift.

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Precautions for Using Pesticides

Pesticides are poisonous and must be used with caution. READ THE LABEL BEFORE OPENING A PESTICIDE CONTAINER. Follow all label precautions and directions, including requirements for protective equipment. Apply pesticides only on the crops or in the situations listed on the label. Apply pesticides at the rates specified on the label or at lower rates if suggested in this publication. In California, all agricultural uses of pesticides must be reported. Contact your county agricultural commissioner for further details. Laws, regulations, and information concerning pesticides change frequently. This publication reflects legal restrictions current on the date next to each pest's name.

Legal Responsibility. The user is legally responsible for any damage due to misuse ofpesticides. Responsibility extends to effects caused by drift, runoff, or residues.

Transportation. Do not ship or carry pesticides together with food or feed in a way that allows contamination of the edible items. Never transport pesticides in a closed passenger vehicle or in a closed cab.

Storage. Keep pesticides in original containers until used. Store them in a locked cabinet, building, or fenced area where they are not accessible to children, unauthorized persons, pets, or livestock. DO NOT store pesticides with foods, feed, fertilizers, or other materials that may become contaminated by the pesticides.

Container Disposal. Dispose of empty containers carefully. Never reuse them. Make sure empty containers are not accessible to children or animals. Never dispose of containers where they may contaminate water supplies or natural waterways. Consult your county agricultural commissioner for correct procedures for handling and disposal of large quantities of empty containers.

Protection of Nonpest Animals and Plants. Many pesticides are toxic to useful or desirable animals, including honey bees, natural enemies, fish, domestic animals, and birds. Crops and other plants may also be damaged by misapplied pesticides. Take precautions to protect nonpest species from direct exposure to pesticides and from contamination due to drift, runoff, or residues. Certain rodenticides may pose a special hazard to animals that eat poisoned rodents.

Posting Treated Fields. For some materials, restricted entry intervals are established to protect field workers. Keep workers out of the field for the required time after application and, when required by regulations, post the treated areas with signs indicating the safe re-entry date. Check with your county agricultural commissioner for latest restricted entry interval.

Preharvest Intervals. Some materials or rates cannot be used in certain crops within a specified time before harvest. Follow pesticide label instructions and allow the required time between application and harvest.

Permit Requirements. Many pesticides require a permit from the county agricultural commissioner before possession or use. When such materials are recommended, they are marked with an asterisk (*) in the treatment tables or chemical sections of this publication.

Processed Crops. Some processors will not accept a crop treated with certain chemicals. If your crop is going to a processor, be sure to check with the processor before applying a pesticide.

Crop Injury. Certain chemicals may cause injury to crops (phytotoxicity) under certain conditions. Always consult the label for limitations. Before applying any pesticide, take into account the stage of plant development, the soil type and condition, the temperature, moisture, and wind. Injury may also result from the use of incompatible materials.

Personal Safety. Follow label directions carefully. Avoid splashing, spilling, leaks, spray drift, and contamination of clothing. NEVER eat, smoke, drink, or chew while using pesticides. Provide for emergency medical care IN ADVANCE as required by regulation.