Pheromones

Crops

Identification of Petitioned Substance

Pheromones are volatile chemicals produced by a given species to communicate with other individuals of the same species to affect their behavior (EPA, 2011). For example, pheromones may signal dominance status, sexual receptivity, danger, and other information. Scientists have isolated and identified a large number of natural pheromones, many of which are now synthesized for use in insect pest management. Synthetic pheromones are currently allowed by the U.S. Department of Agriculture (USDA), National Organic Program (NOP) for use in insect management (7 CFR 205.601(f)), and many synthetic pheromone products are registered as pesticides by the United States (U.S.) Environmental Protection Agency (EPA).

Pheromones that are approved by EPA as pesticide active ingredients are delivered[1] to target species in a variety of products with varied applications, application methods, and use sites. The EPA Office of Pesticide Programs (OPP) registers specific pheromones as pesticide active ingredients and also registers individual pesticide products containing these active ingredients. Because manufacturers frequently introduce products (e.g., with new delivery methods and ingredient formulations) to the market, the list of EPA-registered pheromone products also changes frequently. Although EPA does not publish a comprehensive list of registered pheromone products, a list can be compiled by searching on-line databases, such as the National Pesticide Information Retrieval System (NPIRS), for products containing pheromones as active ingredients. Based on a search of NPIRS, Appendix A identifies more than 100 commercially available pheromone products currently registered with the EPA for agricultural use. The products are grouped by application method (e.g., puffer, Specialized Pheromone and Lure Application Technology, dispenser, etc.).

The products listed in Appendix A were identified by searching for actively registered products that have 'pheromones' listed as an active ingredient. Because of differences in naming convention, specific chemical ingredients were not included in the database search. Additional search criteria included pheromone delivery system (e.g., ring, fiber, spray, flakes, etc.), trademarked product name (e.g., Checkmate®, NoMate®, Isomate®), and product manufacturer. The majority of the products included in Appendix A are intended for use in managing insects in the order Lepidoptera. Some products are directed for use in managing Japanese beetles and German cockroaches. This list should not be regarded as comprehensive because the search did not include a full analysis of the products registered for each chemical ingredient typically characterized as a component of a pheromone formulation. Attention is given in the Appendix A table to products registered as technical pheromones that are used in pheromone products. These products generally do not have a delivery method specified on their product label, so no delivery method has been specified in the table. A complete list of pheromone products would likely be much larger than the partial list provided in Appendix A because there may be additional manufacturers, delivery methods, and technical pheromones not identified in the search efforts employed for developing Appendix A.

Sixteen pheromone products are specifically included in the Organic Materials Review Institute (OMRI) Products List (2012). Appendix B provides a list of pheromone products that OMRI considered as suitable for use in organic agriculture when issuing its most recent update to the Products List in March 2012. The OMRI Products List does not include all of the commercially available products that would be allowable for use in organic crop production under the current NOP regulations (7 CFR 205.601(f)), and many of the product labels for the EPA registered pheromone products provided in Appendix A indicate that their use in organic agriculture is acceptable. It should be noted that OMRI considers some products to be out-of-scope and beyond resolution for the Products List, including passive pheromone dispensers (OMRI, 2011). OMRI states that:

> "Passive pheromone dispensers are eligible to use List 3 inert ingredients under 7 CFR 205.601(m). The definition is generally considered to include twist-ties, ropes, coils and other retrievable dispensers

[1] See 'Specific Uses of the Substance' for more information on pheromone delivery methods.

where the active pheromone is not in contact with the crop. It is unclear if formulations that are applied to the crop and are not possible to retrieve are passive pheromone dispensers. "

Pheromones have been effective in the control of many insect pests including the Japanese beetle and German cockroach; however most of the products described in Appendix A are utilized in pest management programs for insects belonging to the order Lepidoptera, which includes moths and butterflies. Lepidopteran pheromones are used to disrupt the mating behavior of certain moths whose larvae destroy crops and trees. Many EPA-approved lepidopteran pheromones contain synthetic versions of naturally occurring compounds that are produced by female moths to attract a mate. Generally, the relative amounts of several pheromone chemicals in a pesticide product determine which specific pests are controlled. Table 1 provides details on the use of female moth mating pheromones (synthetic) that are approved by the EPA as pesticide active ingredients (EPA, 2011) to control lepidopteran pests.

Characterization of Petitioned Substance

Composition of the Substance:
Pheromones are produced naturally by many organisms and have been synthetically formulated for agricultural use. The active ingredients in many of the pheromones and pheromone products listed in Appendices A and B and Table 1 are alkenes, which are characterized by at least one double bond between two carbons (O'Leary, 2000).

Insect pheromones are generally comprised of very specific esters (Baldwin, 2011). These chemical compounds are derived by reacting an oxoacid with a hydroxyl compound, such as an alcohol or phenol, or are formed by condensing an acid with an alcohol (Clark, 2004). Many pheromones have been characterized as chiral because they lack an internal plane of symmetry and thus have a non-superimposable mirror image (Mori, 2010).

The majority of known structures for moth pheromones are hydrocarbon chains, usually 10 to 18 carbons in length, with 1 to 3 double bonds and a terminal acetate, alcohol, or aldehyde. Less common structural motifs in moth pheromones include epoxides, ketones, and hydrocarbons with one or more double bonds or methyl branches. These chain lengths can range from C_{10} to C_{23} (Resh and Cardé, 2009). The primary components of sex pheromones (esters) are the most critical part of the chemical complex, but are reliant on the presence or absence of secondary components, which greatly affect an insect's response sequence (Baldwin, 2011).

Properties of the Substance:
Released by many organisms, pheromones are odorless chemicals that affect the behavior of other members of the same species. After an organism releases a pheromone, the liquid pheromone dissipates into the surrounding air and forms a cloud of vapor near the signaling animal (Regnier and Law, 1968). These unique compounds have been identified and synthetically produced in the laboratory for commercial use. In general, many commercially produced pheromone products are considered alkenes. Alkenes are insoluble in water, but are soluble in organic solvents. Alkenes used in synthetic pheromone products are generally liquids and have a lower density than water (O'Leary, 2000). Esters that act as the components of many nonsynthetic and synthetic pheromones are generally of a low molecular weight and are considered to be volatile (Clark, 2004).

Chemical properties of pheromones released by the phylogenic order Lepidoptera (i.e., moths and butterflies) have been researched. Pheromones of Lepidoptera are classified as oxygenated hydrocarbons in a medium-long chain. These chains are generally composed of 10 to 20 carbon atoms and are saturated with up to three double bonds. The end of the chain typically contains a functional group characterized as an alcohol, acetate, or aldehyde (CBC, 2011). As an example, the physical and chemical properties of the codling moth pheromone are provided in Table 2.

Table 1. Female Moth Mating Pheromones Approved as Pesticide Active Ingredients

Pests Controlled	Use Sites	Chemical Name of Pheromone (OPP Chemical Code)	CAS Number
Artichoke plume moth	Artichokes	(Z)-11-Hexadecenal (120001)	53939-28-9
Beet armyworm	Alfalfa, cotton, strawberries, vegetables, tobacco	(Z,E) -9,12-Tetradecadienyl acetate (117203); (Z)-9-Tetradecen-1-ol (119409)	31654-77-0; 35153-15-2
Blackheaded fire worm	Cranberries, fruit	(Z)-11-Tetradecenyl acetate (128980)	20711-10-8
Citrus Leafminer Moth (CLM), *Phyllocnistis citrella*	Ornamental and Agricultural crops (unspecified)	(Z,Z,E)-7,11,13-Hexadecatrienal (029000)	888042-38-4
Codling moth	Fruit, nuts	Lauryl alcohol (001509); Myristyl alcohol (001510); (E,E) -8,10-Dodecadien-1-ol (129028); (Z) -11-Tetradecenyl acetate (128980)	112-53-8; 112-72-1; 33956-49-9; 20711-10-8
Codling moth	Fruit, nuts, ornamental trees/shrubs, uncultivated agricultural areas	(E,E) -8,10-Dodecadien-1-ol (129028)	33956-49-9
Codling moth (*Cydia pomonella*)	Pome fruit, stone fruit, tree nuts	n-tetradecyl acetate	638-59-5
Diamondback moth	Manufacturing use	(Z)-11-Hexadecenyl Acetate (129071)	34010-21-4
Dogwood Borer (DWB) (*Synanthedon scitula*)	Pome fruit, stone fruit, tree nut, and ornamental nursery crops	(E,Z)-2,13-octadecadien-1-yl acetate (117242)	86252-65-5
Dogwood Borer (DWB), *Synanthedon scitula*	Pome fruit, stone fruit, tree nut, and ornamental nursery crops	(E,Z)-2,13-octadecadien-1-ol (117244)	123551-47-3
Douglas fir tussock moth	Douglas fir trees	(Z)-6-Heneicosen-11-one (129060)	54884-65-4
Eastern Pine Shoot Borer	Forest trees, woodland trees	(E)-9-Dodecen-1-ol acetate(119004)	35148-19-7
Grapeberry moth	Grapes, vine fruit	(Z)-9-Dodecenyl acetate (129004)	16974-11-1
Grapeberry moth	Grapes	(Z)-11-Tetradecenyl acetate (128980); (Z)-9-Dodecenyl acetate (129004)	20711-10-8; 16974-11-1
Gypsy moth	Forest trees; Ornamental evergreen trees and shrubs	cis-7,8-Epoxy-2-methyloctadecane (114301)	29804-22-6
Hickory shuckworm	Fruits, nuts, Uncultivated agricultural areas	(E,E) -8,10-Dodecadien-1-ol (129028)	33956-49-9
Hickory shuckworm	Fruit, nuts	Lauryl alcohol (001509); Myristyl alcohol (001510); (E,E) -8,10-Dodecadien-1-ol (129028); (Z) -11-Tetradecenyl acetate (128980)	112-53-8; 112-72-1; 33956-49-9; 20711-10-8
Koa seed worm	Fruit, nuts	(Z)-8-Dodecen-1-yl acetate (128906); (E)-8-Dodecen-1-yl-acetate (128907); (Z)-8-Dodecen-1-ol (128908)	28079-04-1; 38363-29-0; 40642-40-8
Leafrollers (various)	Cranberries, fruit	(Z)-11-Tetradecenyl acetate (128980)	20711-10-8
Light Brown Apple Moth (LBAM), *Epiphyas postvittana*	Orchards, Ornamental Nurseries, Vineyards	9,11-tetradecadien-1-ol, 1-acetate, (9E,11E) (128000)	54664-98-1
Macadamia nut borer	Fruit, nuts	(Z)-8-Dodecen-1-yl acetate (128906); (E)-8-Dodecen-1-yl-acetate (128907); (Z)-8-Dodecen-1-ol (128908)	28079-04-1; 38363-29-0; 40642-40-8
Navel Orangeworm	Orange	(Z,Z)-11,13-Hexadecadienal (000711)	71317-73-2
Obliquebanded leafroller	Fruit	Lauryl alcohol (001509); Myristyl alcohol (001510); (E,E) -8,10-Dodecadien-1-ol (129028); (Z) -11-Tetradecenyl acetate (128980)	112-53-8; 112-72-1; 33956-49-9; 20711-10-8

Pests Controlled	Use Sites	Chemical Name of Pheromone (OPP Chemical Code)	CAS Number
Omnivorous leafroller	Fruit (deciduous), grapes, kiwi, nuts	(E)-11-Tetradecenyl acetate (129019); (Z)-11-Tetradecenyl acetate (128980)	33189-72-9; 20711-10-8
Oriental fruit moth	Fruit, nuts	(Z)-8-Dodecen-1-yl acetate (128906); (E)-8-Dodecen-1-yl-acetate (128907)	28079-04-1; 38363-29-0; 40642-40-8
Oriental fruit moth	Fruit, nuts	(E)-5-Decenyl acetate (117703); (E)-5-Decen-1-ol (078038); (Z)-8-Dodecen-1-yl acetate (128906); (E)-8-Dodecen-1-yl-acetate (128907); (Z)-8-Dodecen-1-ol (128908)	38421-90-8; 56578-18-8; 28079-04-1; 38363-29-0; 40642-40-8
Pandemis leafroller	Fruit	Lauryl alcohol (001509); Myristyl alcohol (001510); (E,E) -8,10-Dodecadien-1-ol (129028); (Z) -11-Tetradecenyl acetate (128980)	112-53-8; 112-72-1; 33956-49-9; 20711-10-8
Peach twig borer	Fruit, nuts	(E)-5-Decenyl acetate (117703); (E)-5-Decen-1-ol (078038); (Z)-8-Dodecen-1-yl acetate (128906); (E)-8-Dodecen-1-yl-acetate (128907); (Z)-8-Dodecen-1-ol (128908)	38421-90-8; 56578-18-8; 28079-04-1; 38363-29-0; 40642-40-8
Peach twig borer	Fruit, nuts, agricultural crops (unspecified)	(E)-5-Decen-1-ol acetate (117703); (E)-5-Decen-1-ol (078038)	38421-90-8; 56578-18-8
Pink bollworm	Cotton	7,11-Hexadecadien-1-ol acetate (114103)	50933-33-0
Pink bollworm	Cotton	(Z,E)-7,11-Hexadecadien-1-yl acetate (114101); (Z,Z)-7,11- Hexadecadien-1-yl acetate (114102)	53042-79-8; 52207-99-5
Sparganothis fruitworm	Cranberries	(E)-11-Tetradecen-1-ol acetate (129019)	33189-72-9
Tomato Leafminer, *Tuta absoluta*	Ornamental and Agricultural crops (Specifically, tomato crops)	(E,Z,Z)-3,8,11-Tetradecatrienyl acetate (011472)	163041-94-9
Tomato pinworm	Eggplant, tomato, vegetables (fruiting)	(Z)-4-Tridecen-1-yl acetate (121901); (E)-4-Tridecen-1-yl acetate (121902)	65954-19-0; 72269-48-8
Western Poplar Clearwing moth (Paranthrene robiniae)	Poplars, white burch, willows, locust	(E,Z)-3,13-octadecadien-1-ol; (Z,Z)-3,13-octadecadien-1-ol	66410-28-4; 66410-24-0
Codling moth (*Cydia pomonella*), obliquebanded leafroller (*Choristoneura rosaceana*), pandemis leafroller (*Pandemis pyrusana*), fruittree leafroller (*Archips argyrospilus*), threelined leafroller (*Pandemis limitata*), and European leafroller (*Archips rosamus*)	Apples, pears, quince and other pome fruits, peaches prunes, plums, nectarines, cherries and other stone fruits, walnut, pecan and other nut crops	Z-9-Tetradecen-1-yl acetate (129109)	16725-53-4
Codling moth (*Cydia pomonella*), obliquebanded leafroller (*Choristoneura rosaceana*), pandemis leafroller (*Pandemis pyrusana*), fruittree leafroller (*Archips argyrospilus*), threelined leafroller (*Pandemis limitata*), and European leafroller (*Archips rosamus*)	Apples, pears, quince and other pome fruits, peaches prunes, plums, nectarines, cherries and other stone fruits, walnut, pecan and other nut crops	Z-11-Tetradecen-1-ol (129021)	34010-15-6
Codling moth (*Cydia pomonella*), obliquebanded leafroller (*Choristoneura rosaceana*), pandemis leafroller (*Pandemis pyrusana*), fruittree leafroller (*Archips argyrospilus*), threelined leafroller (*Pandemis limitata*), and European leafroller (*Archips rosamus*)	Apples, pears, quince and other pome fruits; peaches prunes, plums, nectarines, cherries and other stone fruits; walnut, pecan and other nut crops	Z-11-Tetradecenol (120011)	35237-64-0

Sources: EPA, 2001; EPA, 2011

Table 2. Physicochemical Properties of Codling Moth Pheromone

Physical or Chemical Property	Value
Boiling point	110– 120°C
Specific gravity (25°C)	0.857
Viscosity (25°C)	22.9 centistokes
Flash point	91°C
Vapor pressure (25°C)	1.428×10^{-2} mm Hg
pH	5.6
Refractive index	1.467

Source: CBC, 2011

__Specific Uses of the Substance__:

Pheromones are intraspecific chemicals that are produced by a variety of organisms using different glands, including the exocrine gland, and may also be produced in the gut or cuticle and then emitted to the atmosphere (Bloomquist and Vogt, 2003). Many different types of pheromones are produced for communicating a wide array of messages. Some of these pheromones include sex pheromones (substances produced to attract the opposite sex; usually produced by females to attract males); aggregation pheromones (substances produced by one or both sexes to bring organisms together to feed or reproduce); alarm pheromones (substances produced in response to being attacked that alarms, alerts, or repels others of the same species); and trail pheromones (substances produced to denote the presence of food resources and to signal for colony relocation or movement) (Resh and Cardé, 2009).

Pheromones have been synthesized for use in pest management systems. Specifically, pheromones are used for insect population monitoring, trapping, systems of 'attract and kill', and mating disruption or confusion (Resh and Cardé, 2009). General approaches for the direct management of insect pests using pheromones are described below.

- **Traps and lures.** Pheromone traps can be used to detect the presence and density of insect pests. Monitoring allows agricultural workers to define areas of pest infestation and is particularly useful in areas where the distribution and lifecycle of a particular insect species is not well understood. These traps can be used to identify early incidence of a particular pest. Pheromones can be added to traps in order to attract males searching for a female for mating. Specifically, synthetic lures are placed inside of specially-designed traps. Lures are often enclosed or impregnated in rubber or polyethylene, which provides gradual release of the synthetic pheromones. A trap can be a simple roof structure with a sticky bottom to entrap insects, or a roof over a funnel with a container for retaining insects that fall into a funnel. Mass trapping has been utilized to trap all of a pest population's males in order to prevent the population's females from mating. Mass trapping has been shown to to reduce population densities of target species when population levels are low, but mass trapping has proved to be less effective when population densities are high (Pimentel, 2007).

- **Attract and kill systems.** Attract and kill systems are a more recent approach for pest management, and the purpose of this system is to use a synthetic pheromone to bring a target insect in contact with an insecticide. A mixture of insecticide and pheromones is generally sprayed directly onto the crop so that target organisms are exposed to a lethal dose of insecticide. Attract and kill systems are powerful control strategies because target male insects are removed from the ecosystem. This system has been commonly used in killing the boll weevil and grape root borer moth and requires less insecticide than standard insecticide-only sprays (Welter, 2005a).

- **Mating disruption/confusion.** A target area is saturated with synthetic pheromones so that male insects may become disoriented and unable to locate females for mating. The presence of sufficient synthetic pheromone disrupts the mating patterns of many agricultural pests. Pheromone products containing sex attractants are typically released in agricultural fields and orchards during known breeding times (Muir, 2001). There are two primary mechanisms of mating disruption: competitive and non-competitive disruption:

- Competitive mating disruption involves a competitive attraction, which means that the male insects follow a false plume of pheromones which have been released in the air by ground or aerial application. A number of pheromones serve as mating attractants. Competitive disruption is created between females calling for a mate and the pheromones released for pest management purposes. These natural pheromone blends are typically non-synthetic.
- Non-competitive disruption, which involves the release of an unnatural blend of synthetic pheromones. An unnatural blend of pheromones may be an effective camouflage of natural pheromone trails and can disrupt the ability of the male to orient by creating sensory imbalance. The end result is mating that is either delayed or prevented (Carter, 2003; Miller et al., 2006). This method has been shown to be particularly effective with controlling the pink bollworm, lesser peachtree borer, citrus leafminer, grape berry moth, artichoke plume moth, codling moth, and gypsy moth. Because high cost can be a concern, these systems are primarily used in cases where there are existing issues with insecticide resistance, an effective and low-cost insecticide is not available for commercial use, the use of insecticides could disrupt biological control, or the general area of use is considered to be environmentally sensitive (Baldwin, 2011). Several products that contain pheromones for mating disruption are listed by OMRI as allowed for use in organic agriculture. Please see Appendix B for a list of these products.

Pheromone compounds for some insects are so complex that they have yet to be synthesized in their entirety or to be delivered to target species effectively using commercially available methods. In general, sex pheromones are very specific and their specificity is generally derived from the isomeric configuration of the compound, the time and rate of release, and the ratio of chemical components (Baldwin, 2011).

The pheromone delivery systems most commonly used in agriculture are described in more detail below.

- **Passive pheromone dispenser (including traps and lures)**. Passive dispensers use simple diffusion (i.e., moving a molecule across a membrane without the use of physical or chemical energy) to release pheromones into the surrounding environment. Passive dispensers also have been described by the National Organic Standards Board (NOSB) as those which emit pheromones by volatilization rather than by spray and produce a concentration of pheromones in a limited area (NOSB, 2011a). Passive dispenser technology is used to disrupt the mating patterns of insect pests in the vicinity of the dispensers and also used in products designed to trap and lure insect pests. Passive dispensers release pheromones that draw insects away from agricultural crops and towards the pheromone-releasing dispensers.

  The most commonly used products are pheromone-impregnated polymer spirals, ropes, or tubes. The use of wires, clips, or circular twin tubes allows these dispensers to be twist-tied, draped, or clipped directly onto the plant. Application rates vary from one to several dispensers per tree and can be labor intensive. These products are reported to cost more than other chemical control programs, especially in high pest pressure situations where supplemental insecticides would be needed for acceptable control (Biddinger and Krawczyk, 2009). Historically, passive dispensers have been observed to produce unreliable delivery profiles since they are temperature-sensitive, relying only on the ambient temperature, and time-dependent. They are also limited to releasing one component per device (Witzgall, 2001). Flaws have been identified with this method and can be illustrated by the example of the control of codling moths in Swedish apple orchards. Witzgall (2001) reported that 90 percent of pheromones applied using passive dispenser technology was released outside codling moth flight period, mainly during daytime at peak ambient temperatures. In addition, dispensers must be applied early in season when population densities are still low, while their release rates decrease during the season, as population densities start to increase (Witzgall, 2001).

- **Retrievable polymeric pheromone dispenser.** Retrievable polymeric dispensers are defined as a "solid matrix dispenser" delivering pheromones "at rates less than or equal to 150 grams active ingredient (AI)/acre/year" that is "placed by hand in the field and is of such size and construction that it is readily recognized and retrievable" (40 CFR 180). These dispensers are not in direct contact with crops (chemicals serve as mating attractants).

- **Spray method and microencapsulated pheromones**. Microencapsulated pheromones (MECs) are very small droplets (i.e., 10-190 micrometers in diameter) of pheromone enclosed within polymer capsules that control the pheromone release rate (Welter, 2005a). MECs are manufactured to be small in size so that they can be applied in water through normal airblast sprays in the same manner as conventional pesticides. Pheromones must be re-applied several times in a season for a target pest because residual activity is generally four to six weeks. Rainfall may reduce residual activity following application, so the use of a spray adjuvant is often recommended. Currently, the only effective materials that can be applied using the spray method are for the treatment of Oriental fruit moth, peachtree, and lesser peachtree borers. Formulations for codling moth and several species of leafrollers are commercially available but have not been observed to provide reliable control. Sprayable pheromones are not registered for organic fruit production because of the polymer capsulation (Biddinger and Krawczyk, 2009).

- **Hollow fibers.** Used in mating disruption programs since the 1970s, these products consist of an impermeable, short tube that is sealed at one end and then filled with pheromones. After a short initial burst of pheromones, the emission rate remains fairly constant. Application may require specialized aerial or ground equipment (Welter et al., 2005a).

- **High-emission dispensers.** High-emission dispensers were developed to deliver large quantities of pheromones while using fewer dispensers, thus reducing labor costs. Mechanical puffers, manufactured by Suttera, are used for mating disruption and confusion. A battery-powered, automatic metered dispenser releases a high emission aerosol or 'puff' of pheromone at fixed time intervals (generally every 15 minutes) for a 12-hour period during normal mating time (at night). The labeled use of this product indicates that only two puffers should be placed on every one acre of land; however the number of units required per acre varies depending on land/orchard size and patterns of distribution (Welter et al., 2005a). The use of puffer systems can produce significant cost savings because less labor is required in comparison to hand application, but, depending on pest pressure and surrounding landscape, applications of additional pheromones along field borders using hand dispensers may be needed (Biddinger and Krawczyk, 2009). If puffers are to be considered active dispensers of pheromones because they are mechanical in nature, then, in accordance with 7 CFR 205.601, EPA List 3 inerts would not be permitted for use with puffer dispensers (Welter et al., 2005b).

- **Other**. Other pheromone dispensing methods are in development and not yet commercially available. In addition, other alternative methods include the aerial or ground application of pheromone-impregnated flakes, and the use of polymer bags filled with large doses of pheromone (Biddinger and Krawczyk, 2009).Specialized Pheromone and Lure Application Technology (SPLAT™) is a proprietary base matrix formulation of biologically inert materials used to control the release of semiochemicals with or without pesticides. SPLAT products include pheromones that prevent the mating and reproduction of lepidopterous insects and can be applied as a spray using hand, aerial, or group equipment. SPLAT products for the control of oriental fruit moth, pink bollworm, codling moth, gypsy moth, light brown apple moth, carob moth, and citrus leafminer are commercially available (ISCA Technologies, 2010).

Approved Legal Uses of the Substance:

Pheromones are considered pesticides according to the definition set forth by the NOP (7 CFR 205.2). The NOSB approved the listing of pheromones as approved for use in organic agriculture in 1995. In 2002, the NOSB voted to allow the use of List 3 inerts in passive pheromone dispensers, through approval of the following annotation:

> Pheromones -includes only EPA-exempt pheromone products, EPA-registered pheromone products with no additional synthetic toxicants unless listed in this section, and any inert ingredients used in such pheromone formulations that are not on EPA List 1 (Inerts of toxicological concern) or EPA List 2 (Potentially toxic inerts), *provided* the pheromone products are limited to passive dispensers. Pheromone products containing only pheromones, active ingredients listed in this section, and List 4 inerts may be applied without restriction (NOSB, 2011b).

Currently, the U.S. Department of Agriculture (USDA) permits the use of synthetic pheromones in insect management (7 CFR 205.601(f)). Inert ingredients on the EPA List 3 (inerts of unknown toxicity) and the EPA List 4 (inerts of minimal concern) may be used in conjunction with synthetic pheromone substances (7 CFR 205.601(m)); however, the EPA List 3 inerts are only allowed for use in passive pheromone dispensers (7 CFR 205.601(m)(2)). Additionally, lures and repellents using nonsynthetic or synthetic substances (including pheromones) on the National List are permitted for use in organic pest control (7 CFR 205.271(b)(2)).

As shown in Appendix A, a large number of products containing active ingredients that are considered to be synthetic pheromones are currently registered with the EPA for use as agricultural pesticides. For reasons discussed in the "Identification of the Petitioned Substance "section, Appendix A should be considered as a partial, non-exhaustive list of pheromone containing products registered with the EPA. For example, there are over 60 individual pesticide products containing active ingredients that are considered to be pheromones used for the mating disruption of moths belonging to the order Lepidoptera. Each synthetic mixture of pheromones must be approved for use as an active ingredient in a pesticide product and each pesticide product requires a unique EPA Registration Number (EPA, 2011). The majority of the active ingredients in products listed in Appendix A do not require a food clearance or tolerance (EPA, 2001).

The EPA promotes the use of pheromone products because they present a lower risk than conventional pesticides. For example, the EPA has initiated a regulatory relief program that allows flexible confidential statements of formula for pheromone experimental use permits (EUP) to allow for active ingredient adjustments during the course of experimentation. The EPA has also published generic tolerances and relaxed the acreage cutoff when a EUP is required.

The EPA established the following special regulations as a result of the pheromone regulatory relief program (EPA, 2010).

- Plant volatiles and pheromones (Z-2-isopropenyl-1-methylcyclobutaneethanol; Z-3,3-dimethyl-Δ1,β-cyclohexaneethanol; Z-3,3-dimethyl-Δ1,α-cyclohexaneethanal; E-3,3-dimethyl-Δ1,α-cyclohexaneethanal combination); exemption from the requirement of a tolerance (40 CFR 180.1080);
- 3,7,11-Trimethyl-1,610-dodecatriene-1-ol and 3,7,11-trimethyl-2,6,10-dodecatriene-3-ol; exemption from the requirement of a tolerance (40 CFR 180.1086);
- GBM-ROPE; exemption from the requirement of a tolerance (40 CFR 180.1097);
- Isomate-C; exemption from the requirement of a tolerance (40 CFR 180.1103);
- Inert ingredients of semiochemical dispensers; exemption from the requirement of a tolerance (40 CFR 180.1122);
- Arthropod pheromones; exemption from the requirement of a tolerance (40 CFR 180.1124);
- Codlure, (E,E)-8,10-Dodecadien-1-ol; exemption from the requirement of a tolerance (40 CFR 180.1126); and

- Lepidopteran pheromones; exemption from the requirement of a tolerance (40 CFR 180.1153)

Specifically, the EPA exempts straight-chained lepidopteran pheromones from the requirement of a tolerance in or on all raw agricultural commodities in the following situations: (1) when applied to growing crops at a rate not to exceed 150 grams of active ingredient/acre/year in accordance with good agricultural practices, and (2) when applied as a post-harvest treatment to stored food commodities at a rate not to exceed 3.5 grams active ingredient (AI)/1,000 square feet/year (equivalent of 150 grams AI/acre/year) in accordance with good agricultural practices (40 CFR 180.1153 [a] and [b]) (EPA, 2001).

Action of the Substance:
Commercially-available synthetic pheromone products do not kill insects, but are effective in significantly influencing the behavior of insects through the olfactory system by mimicking naturally-produced insect pheromones. In nature, following release, volatile pheromone molecules are adsorbed onto the surface of the insects' antennae. The molecules then diffuse into the interior of the insect through pores in the cuticle (i.e., the outer layer of the insect). Pheromone molecules are generally lipophilic and are transferred within the insect to chemosensory membranes. A chemical complex is formed on the chemosensory membrane, and receptor proteins transform the chemical signal into an electrical signal. This signal directs the insect to change its behavior. A synthetic pheromone can elicit the same behavioral response. For example, a synthetic sex pheromone can be used to signal the insect to inactivate release of the pheromone and halt mate searching (Krieger, 2001).

Combinations of the Substance:
Synthetic, unnatural blends of pheromones are mixtures of chemicals that produce the same effects on insects as natural pheromones. The active ingredients of several commercially-available synthetic pheromone products are provided in Appendices A and B and Table 1. Manufacturers produce different formulations to alter the behavior of specific species of insects (EPA, 2011).

Status

Historic Use:
Insect pheromones were discovered in the mid-1900s and since that time thousands have been identified. Synthetic pheromones have become an important component of integrated pest management (IPM) programs. There have been three main uses of synthetic pheromones in the IPM of insects, as detailed below (Seybold and Donaldson, 1998).

The primary application of synthetic pheromones in IPM has been in monitoring populations of insects to determine if particular species are present or absent in an area or to determine if an elevated number of a particular species is present to warrant costly treatment. Monitoring—an important component of any IPM program—has been used extensively to track the nationwide spread of certain major agricultural pests such as the gypsy moth, Mediterranean fruit fly (medfly), and Japanese beetle. Pheromone traps have been used to monitor the spread of exotic and invasive insect pests and have also been used to provide information on insect patterns of movement (Seybold and Donaldson, 1998).

Synthetic pheromones have also been used in IPM to mass trap insects in order to remove large numbers of insects from the breeding and feeding population. Massive reductions in the population density of pest insects ultimately help to protect agricultural resources. Successful trapping efforts have occurred with the pine bark beetle and ambrosia beetle, two threats to the logging industry. Mass trapping has also been used successfully against the codling moth, a serious pest of apples and pears (Seybold and Donaldson, 1998).

Thirdly, synthetic pheromones have been used in IPM to disrupt mating in populations of insects. This application has been most effectively used with agriculturally-relevant moth pests. Synthetic pheromone product is dispersed into crops creating plumes that can attract males away from females that are waiting to mate or prevent males from locating a female with which to mate. This causes reductions in mating and thus reduces the population density of the pests. In some cases, the effect has been so great that the pests have been locally eradicated (Seybold and Donaldson, 1998).

OFPA, USDA Final Rule:

USDA permits the use of synthetic pheromones in insect management (7 CFR 205.601(f)). Inert ingredients on the EPA List 3 (inerts of unknown toxicity) and the EPA List 4 (inerts of minimal concern) may be used in conjunction with synthetic pheromone substances (7 CFR 205.601(m)); however, the EPA List 3 inerts are only allowed for use in passive pheromone dispensers (7 CFR 205.601(m)(2)).

International

The Canadian General Standards Board permits the use of both synthetic and nonsynthetic pheromones as a crop production aid. Pheromones are permitted for use in pheromone traps or dispensers. List 1 or List 2 formulants[2] used in conjunction with synthetic pheromone products are prohibited; however List 4A, List 4B[3], or nonsynthetic products are permitted for this use (Canadian General Standards Board, 2011).

The European Economic Community (EEC) Council Regulation (EC) No 889/2008, Annex II permits the use of pheromones as an attractant or sexual behavior disrupter for use in traps or dispensers. These pheromone products are regarded as plant protectors. Pheromone dispensers and traps are the only devices from which environmental release of the chemical product is permitted (EC No 889/2008).

The CODEX Alimentarius Commission describes synthetic pheromone products as acceptable for use in traps and dispensers (GL 32-1999 Guidelines for the Production, Processing, Labeling, and Marketing of Organically Produced Foods; CODEX Alimentarius Commission, 2001).

Evaluation Questions for Substances to be used in Organic Crop or Livestock Production

Evaluation Question #1: What category in OFPA does this substance fall under: (A) Does the substance contain an active ingredient in any of the following categories: copper and sulfur compounds, toxins derived from bacteria; pheromones, soaps, horticultural oils, fish emulsions, treated seed, vitamins and minerals; livestock parasiticides and medicines and production aids including netting, tree wraps and seals, insect traps, sticky barriers, row covers, and equipment cleansers? (B) Is the substance a synthetic inert ingredient that is not classified by the EPA as inerts of toxicological concern (i.e., EPA List 4 inerts) (7 U.S.C. § 6517(c)(1)(B)(ii))? Is the synthetic substance an inert ingredient which is not on EPA List 4, but is exempt from a requirement of a tolerance, per 40 CFR part 180?

(A). Yes, the substance, which is a class of related compounds, contains active ingredients in the category of pheromones.

(B). The substance is not an inert ingredient, but may be formulated with chemicals on the EPA List 3 (inerts of unknown toxicity) or EPA List 4. List 3 inert ingredients are restricted for use in passive pheromone dispensers (7 CFR 205.601).

---

[2] Health Canada's Pest Management Regulatory Agency (PMRA) categorizes formulants found in pest control products registered in Canada based on the level of concern with respect to human health and the environment. List 1 contains formulants identified as being of significant concern with respect to their potential adverse effects on health and the environment. These formulants meet defined criteria for carcinogenicity, neurotoxicity, chronic effects, adverse reproductive effects and ecological effects as well as criteria as defined under the Toxic Substances Management Policy (TSMP) or are substances designated under the Montreal Protocol. List 2 contains formulants that are considered potentially toxic, based on structural similarity to List 1 formulants or on data suggestive of toxicity (PMRA, 2010).

[3] List 4B includes formulants, some of which may be toxic, for which there are sufficient data to reasonably conclude that the specific use pattern of the pest control product will not adversely affect public health and the environment. List 4A contains formulants that appear on the USEPA Minimum Risk Inerts List, which are generally regarded to be of minimal toxicological concern, as well as substances commonly consumed as foods (PMRA, 2010).

<u>Evaluation Question #2:</u> Describe the most prevalent processes used to manufacture or formulate the petitioned substance. Further, describe any chemical change that may occur during manufacture or formulation of the petitioned substance when this substance is extracted from naturally occurring plant, animal, or mineral sources (7 U.S.C. § 6502 (21)).

Commercial pheromone products are chemically synthesized using processes that are unique for each chemical (Mori, 2010). In addition, many pheromone products are formulated as mixtures with inert ingredients. The formulations also may contain ultra-violet-stabilizers or antioxidants to preserve the pheromones from rapid degradation (APHIS, 2010b). The specific compositions of these formulations are generally considered to be confidential business information and are not publicly disclosed.

Many pheromones are chiral molecules, meaning that they lack an internal plane of symmetry and thus have a non-superimposable mirror image. Methods for synthesis of chiral pheromones include derivation from natural products (i.e., the insect's natural pheromone), enantiomer separation (optical resolution), and chemical or biochemical asymmetric synthesis (Mori, 2010).

<u>Evaluation</u> <u>Question #3:</u> Is the substance synthetic? Discuss whether the petitioned substance is formulated or manufactured by a chemical process, or created by naturally occurring biological processes (7 U.S.C. § 6502 (21)).

Although pheromones are produced naturally by insects and other organisms, commercial-scale production requires chemical synthesis. The synthesis of these chemicals is complex and typically involves multiple conversion steps (Mori, 2010).

<u>Evaluation Question #4:</u> Describe the persistence or concentration of the petitioned substance and/or its by-products in the environment (7 U.S.C. § 6518 (m) (2)).

Following the release of natural pheromones by insect species and the use of synthetic pheromones for IPM, the substances dissipate rapidly into the environment. Dissipation primarily occurs through volatilization and degradation. Degradation typically takes place through oxidation of the double bonds characteristic of alkenes (CBC, 2011). Release of synthetic pheromones occurs slowly over time (except in cases using synthetic pheromone delivery methods such as puffers[4]) and dissipation of all pheromone products into the air is likely (EPA, 2011). All pheromones (i.e., synthetic and nonsynthetic) are considered to be generally non-toxic and have low persistence in the environment (Chiras, 2010).

<u>Evaluation Question #5:</u> Describe the toxicity and mode of action of the substance and of its breakdown products and any contaminants. Describe the persistence and areas of concentration in the environment of the substance and its breakdown products (7 U.S.C. § 6518 (m) (2)).

Pheromones do not act as insecticides because they do not kill target insect species. Instead, they are effective in influencing the behavior of insects through their olfactory system by either mimicking naturally-produced insect pheromones (i.e., natural blends) or producing signals that disrupt the sensory abilities required for locating mates (i.e., unnatural blends). In nature, following release into the environment, pheromones come into contact with the insect's antennae and are adsorbed. The molecules then diffuse into the interior of the sensilla through pores in the cuticle, or outer layer, of the insect. Pheromone molecules are generally lipophilic and are transferred through the hydrophilic sensillum lymph to the chemosensory membranes by pheromone-binding proteins. A complex is formed and receptor proteins transform the chemical signal into an electrical signal. This signal directs the insect to change its behavior. A synthetic pheromone can elicit the same behavioral response. For example, a synthetic sex pheromone can be used to signal the insect to inactivate the pheromone and halt mate searching (Krieger, 2001).

---

[4] Puffers release a larger concentration of pheromone product; however, their timed release ensures that an excessive concentration is not released to the environment. Timed release prevents oversaturation of the surrounding air with pheromones.

Nonsynthetic and synthetic pheromones are known to dissipate quickly in air and mainly through volatilization and degradation. For pheromones containing a double carbon bond (characteristic of all alkenes), degradation occurs via oxidation of the double bonds of the chain of carbon atoms and by other types of oxidizing degradation. The enzymes that bring about the degradation of the pheromone residues are present throughout nature (CBC, 2011).

In general, synthetic insect pheromones have been observed to have a very low level of risk associated with their use. However, it is important to note that only a small fraction of known insect pheromones (which have effects that are mimicked by commercially available synthetic pheromones) have been thoroughly examined for their toxic or other pharmacological effects on non-target (including mammalian) species. Toxicity information is available for some of the chemicals found in OMRI-listed synthetic insect pheromone products and is presented in Table 3 (Krieger, 2001).

Table 3. Acute Toxicity of Some Insect Pheromones

Compound	Target Species	Oral LD_{50} (mg/kg)–Rat	Dermal LD_{50} (mg/kg)–Rat	Inhalation LC_{50} (mg/L)–Rat
(E, E)-8, 10-Dodecadien-1-ol	Codling moth, oriental fruit moth, hickory shuckworm	>3,250	-	-
(Z, Z)-7, 11-Hexadecadien-1-yl acetate	Pink bollworm	>15,000	-	>3.33
(E)-11-Tetradecen-1-yl	Omnivorous leafroller	>5,000	>5,000	>16.9
(Z)-4-Tridecen-1-yl acetate	Tomato pinworm	>5,000	>2,000	>5
(Z)-9-Tetradecenal	Codling moth and hickory shuckworm	>5,000	-	-

Source: Krieger, 2001

The "Consensus Statement on Human Health Aspects of the Aerial Application of Microencapsulated Pheromones to Combat the Light Brown Apple Moth" issued by the California Department of Pesticide Regulation and Office of Environmental Health Hazard Assessment (Cal DPR-OEHHA) reiterated that EPA determined pheromones targeted at species of the Lepidoptera order (moths and butterflies) are sufficiently similar to be toxicologically grouped, and that toxicity is minor enough to be exempt from the requirement of a tolerance, as discussed in "Approved Legal Uses of the Substance." A study on the toxicity of a specific lepidopteran pheromone active ingredient can be applied to any other lepidopteran pheromone active ingredients. Studies using laboratory animals have shown that acute oral toxicity of lepidopteran pheromones is very low (LD_{50} > 5,000 mg/kg). Some potential exists for mild to moderate respiratory irritation and skin irritation with high exposure levels greater than 2,000 mg/kg. The active ingredients in CheckMate® LBAM-F, used in the Light Brown Apple Moth (LBAM) Eradication Program in California in 2007, include (E)-11-tetradecen-1-yl acetate and (E,E)-9,11 tetradecadien-1-yl acetate (Cal DPR-OEHHA, 2007; Rose, 2008).

As previously discussed, USDA permits the use of inert ingredients on EPA List 4 (inerts of minimal concern) in conjunction with synthetic pheromones (7 CFR 205.601(m)); inert ingredients on EPA List 3 (inerts of unknown toxicity) are allowed only for use in passive pheromone dispensers (7 CFR 205.602(m)(2)). Inert ingredients in synthetic pheromone product formulations are meant to improve performance or dilute the active ingredient, or can result as a byproduct of or reactant used in the manufacturing processes (Cal DPR-OEHHA, 2007; Rose, 2008). For example, the inert ingredients in Checkmate® LBAM-F include a large proportion of water, and:

- 1,2-benzisothiazol-3-one (antibacterial agent/fungicide),
- 2-hydroxy-4-n-octyloxybenzophenone (UV-blocking agent),
- Cross linked polyurea polymer (for microencapsulation of the active ingredient),
- butylated hydroxytoluene (antioxidant commonly used as food preservative),

- polyvinyl alcohol (lubricant, component of white glue), and
- sodium phosphate and ammonium phosphate (common chemicals, also known as phosphoric acid).

The inert ingredients in the pheromone formulation include known irritants, sensitizers, and allergens, and compounds that may potentially be linked to asthma, cancer, and endocrine disruption. Additionally, industrial production of polyurea plastic has been shown to induce acute bronchial constriction in exposed workers, leading some to question the risks associated exposure to the polyurea plastic capsules (Rose, 2008).

Synthetic pheromone products can be applied for pest management using a variety of techniques. In large-scale applications (e.g., large scale use of spray method or puffer), the use of gas chromatography has failed to detect concentrations of synthetic pheromones on treated crops. It is unlikely that other methods for pheromone dispensing (e.g., passive dispensers or hand spray) would release a volume of pheromones large enough to produce residues on agricultural goods. However, some synthetic pheromone products, such as those containing a mixture of (E,E)-9,11-tetradecadienol acetate and (E)-11-tetradecenol, were observed to be absorbed by plant leaves when the product was released in the airstream in high volumes. The plant leaves were able to act as pheromone baits in the agricultural field (Krieger, 2001).

<u>Evaluation Question #6:</u> Describe any environmental contamination that could result from the petitioned substance's manufacture, use, misuse, or disposal (7 U.S.C. § 6518 (m) (3)).

Nonsynthetic and synthetic pheromones are considered to be non-toxic, and the EPA characterizes them as causing negligible harm to the environment through manufacture, use, and disposal processes (EPA, 2011, 2011). The use patterns of pheromones vary and include dispensers impregnated with pheromones designed to release pheromones by volatilization, traps laced with pheromones used to attract insects, puffers producing periodic mists, and sprays of MECs. Pheromones used to attract insects to traps emit small quantities of the material that allow the insects to follow a trail to the trap. Other methods of using pheromones involve filling a tree canopy or entire orchard with pheromone in order to confuse the target insect (CBC, 2011). The EPA states that the appropriate use of synthetic and nonsynthetic pheromones for IPM will not cause environmental contamination and can cause only negligible harm to the environment (EPA, 2011).

If synthetic pheromone products are misused, they might not be effective for monitoring or controlling insect populations. In some cases, these products are used for trapping insects in order to monitor the presence of invasive species and population density. If too much pheromone is released to the environment, the air becomes saturated and could actually repel the insects away from the trap. When pheromones are released at concentrations that are too low, the signal carried in the pheromone might be lost to the target species and the product will not be effective. The substance could then degrade in the air before it reaches the target species (EPA, 2001).

The USDA's Animal Plant Health Inspection Services (APHIS) reviewed the use of light brown apple moth mating disruption pheromone dispensers for the control of the light brown apple moth. APHIS and the California Office of Environmental Health Hazard Association received the specific formulation of the substances contained within this pheromone mixture and evaluated the environmental effects from the formulation. In general, these organizations concluded that no significant environmental impact or risk to human health would result from the other pheromone ingredients in the mixture. However, there were reports of potentially adverse effects on human health. See Evaluation Question #10 for additional details. Mammalian toxicity testing for this particular pheromone formulation was not conducted due to the large amount of plastic material that would have to be consumed by test animals to reach the limit dose in each of the exposure studies (APHIS, 2010b).

Product labels provide guidance on the disposal of pheromone products and passive pheromone dispensers. Labels advise users to dispose of all pheromone products properly in an appropriate waste container and typically include a warning prohibiting the disposal of passive pheromone dispensers in or near water (APHIS, 2010a). Leaving pheromone products and dispensers in the field beyond the period of intended use could result in the unintentional release of pheromones to the agroecosystem. However adverse effects would be minimal following this type of misuse because of the presumed low toxicity of pheromone compounds. Also, as discussed in Evaluation Question #5, pheromones are known to dissipate quickly in air through volatilization and degradation, and the rate of passive release would decline as the dispenser is depleted (CBC, 2011). In addition, the chemical formulation for each pheromone product is generally designed to alter the behavior for a specific insect species which might not be present after the period of intended use (Baldwin, 2011).

Evaluation Question #7: Describe any known chemical interactions between the petitioned substance and other substances used in organic crop or livestock production or handling. Describe any environmental or human health effects from these chemical interactions (7 U.S.C. § 6518 (m) (1)).

No information has been identified on known chemical interactions between pheromones and other substances used in organic agriculture.

Evaluation Question #8: Describe any effects of the petitioned substance on biological or chemical interactions in the agro-ecosystem, including physiological effects on soil organisms (including the salt index and solubility of the soil) crops, and livestock (7 U.S.C. § 6518 (m) (5)).

Natural pheromones are produced by organisms to act as behavior-altering agents for members of its own species and may signal information as diverse as the dominance of an individual in a colony, the sexual receptivity of the producer, or perceived dangers. Formulations of synthetic pheromones are designed to affect and alter the behavior of a target insect species in the same manner as the pheromones naturally produced by a particular species (Baldwin, 2011).

While the appropriate use or pheromones is unlikely to adversely impact ecological health, they are known to alter insect behavior. Use of pheromones does result in many female insects failing to mate and lay eggs, and therefore can decrease the population of the target insect species over time (Cal DPR-OEHHA, 2007). This could have unintended consequences for ecological health. For example, if the targeted insect population is kept from mating for a long period of time, a decrease in population levels could occur that has potential to eradicate the species from the area. If pheromone use is timed to delay mating until after a crucial time for the agricultural crop, decreasing population levels may not be as much of a concern because the species could resume mating when the pheromone was not in use. However, a delay in mating and subsequent lifecycle stages could potentially negatively correspond with seasonal aspects like onset of colder weather, or impact biodiversity by altering the availability of the insects as a food source to higher-trophic level organisms at crucial times. It is important to note, however, that many of the insect species targeted by the pheromones and pheromone mixtures discussed in this report are non-native invasive insect species, and their presence may have the potential to devastate agricultural crops and nurseries or other native plant or animal species.

Adverse effects on non-target organisms (e.g., mammals, birds, aquatic organisms) from the use of synthetic or nonsynthetic pheromone products are not expected because they are generally considered non-toxic, they are generally released slowly and in small amounts, and they are designed to attract a specific species. Because synthetic and nonsynthetic pheromone products dissipate quickly in air, it is unlikely that soil organisms would be affected. The substance would likely have dissipated before having the opportunity to permeate the soil (CBC, 2011).

Microencapsulated pheromone formulations may pose a risk to the health of bees, which in some instances can be considered as livestock. The inert ingredients found in microencapsulated pheromone products can be sticky and viscous, and the wings and bodies of worker bees could become coated in the material causing disorientation, struggle to fly, and death. Microcapsules also can stick electrostatically to the worker bees in the same way that pollen does, and be brought into the hive and fed to other bees, including the queen bee, brood, and emerging adults/immature bees (Upton et al., 2008). Please see Evaluation Question #9 for more information on the potential effects of MECs on the health of bees.

Evaluation Question #9: Discuss and summarize findings on whether the petitioned substance may be harmful to the environment (7 U.S.C. § 6517 (c) (1) (A) (i) and 7 U.S.C. § 6517 (c) (2) (A) (i)).

In general, impacts on the environment are unlikely and the EPA reports that adverse effects on non-target organisms from the use of pheromone products are not expected because these products are generally released to the environment in very small amounts and act on select species of insects. Therefore risks would be minimal because exposure is likely to be very minimal. Appropriate precautionary labeling of end-use products is required by the EPA and these efforts will further minimize potential exposures and mitigate risks to non-target organisms (EPA, 2001).

Pheromones are species-specific, so impacts on non-target species including birds, mammals, and aquatic organisms are expected to be low according to the U.S. EPA (Cal DPR-OEHHA, 2007). However, as discussed in "Specific Uses of the Substance," specificity of natural pheromone systems is derived from the isomeric configuration of the compound, the time and rate of release, and the ratio of chemical components. An insect's response sequence is reliant on the presence or absence of secondary components (Baldwin, 2011). Synthetic pheromones are less complex and unique in their chemical combinations and, therefore, are not as species-specific as natural pheromone systems. Closely related non-target species can exhibit small levels of attraction to the applied pheromones; for example pheromones targeting the invasive light brown apple moth in California also attracted native moth species from the Pyralidae and Torticidae families (CDFA, 2009; APHIS 2010a). A search of databases, including pherobase.com, for records of moth species in Monterey County, California and their pheromone systems found that 14 out of 79 species (18%) in the county with known pheromones shared sensitivity to the pheromones used in Checkmate® LBAM-F and OLR-F [(E)-11-tetradecen-1-yl acetate, (E,E)-9,11-tetradecadien-1-yl acetate, and (Z)-11-tetradecen-1-yl acetate)] (California LBAM Eradication Plan, 2008). Given that 942 species of moths are present in Monterey County (863 with unknown pheromones), authors estimated that 168 total moth species were susceptible to mating disruption as a result of the use of Checkmate® synthetic pheromone formulations intended to disrupt mating in one species, the light brown apple moth (California LBAM Eradication Plan, 2008).

Microencapsulated pheromone formulations, specifically, may pose a risk to the health of bees, which play a crucial role as pollinators in many ecosystems, including agricultural ecosystems upon which humans depend. Microcapsules used in pesticide and pheromone spray delivery systems are typically 10-190 micrometers in diameter, which is comparable to the 15-100 micrometer size of a pollen grain. Microcapsules are dispersed using spray methods resulting in microcapsules containing pheromones and their associated emulsifiers, surfactants, and other inert ingredients suspended in the air and coating the surface of plants. The inert ingredients can be sticky and viscous, and the wings and bodies of worker bees could become coated in the material causing disorientation, struggle to fly, and death. Further, microcapsules can stick electrostatically to the worker bees in the same way that pollen does, and be brought into the hive and fed to other bees, including the queen bee, brood, and emerging adults/immature bees. Microcapsules brought into the hive and stored would release the pheromone as intended over the course of 30-90 days, equivalent to 2-3 generations of bees (Upton et al., 2008). California Department of Food and Agriculture (CDFA) reports that an experimental trial showed that no significant mortality or other adverse effects were elicited in honeybees exposed to high concentrations of light brown apple moth pheromones, and that honeybees were unlikely to collect or ingest the microcapsules while foraging (CDFA, 2009). No other information was found to identify whether bees are sensitive to synthetic pheromones or the inert ingredients in pheromone formulations used in crop management. However, it has been noted that Colony Collapse Disorder (CCD), which has caused the loss of over one third of honeybee colonies in the U.S. since 2005, may be caused by an array of suspected contributing factors including stress from chemicals used in crop management, climate change, pollination of monocultures, stress from transportation of bees for pollination, disease, etc. (Upton et al., 2008).

Impacts on the environment may also vary depending on the pheromone delivery method employed for IPM. In 2009, CDFA prepared a Programmatic Environmental Impact Report (EIR) for the eradication of the light brown apple moth. Part of the report included a comparison of potential impacts between three mating disruption pheromone application methods: twist-ties (a type of passive dispenser), ground applications of a thick pheromone-containing matrix applied to trees and utility poles, and aerial applications. The EIR found that no program had significant or unavoidable impacts; most categories evaluated were rated as "no impact." In terms of differences between types of pheromone application methods, the EIR ranked twist-ties as having no impact on beneficial insects and agriculture, no potential for exceedance of toxicity reference values for nontarget invertebrates and pollinators, and no impact associated with exposure of terrestrial wildlife, fish, or human health due to accidental spills. The other two methods had less-than-significant potential impacts in these categories. Similarly, twist-ties had no impact on noise, whereas the other two had minor potential to temporarily increase noise levels. The EIR concluded that twist-ties were the environmentally superior choice. Twist-ties placed near aquatic environments could cause short-term disturbance of aquatic species; if spawning anadromous salmonids are present mitigation would be required. However this impact could be avoided by limiting the use of twist-ties near streams and rivers (CDFA, 2009).

Twist-ties consist of the active pheromone ingredient in a porous plastic matrix (CDFA, 2009). One benefit of twist-tie pheromone applications over other methods, such as aerial spray applications, is that any of the product's inert ingredients stay on the physical part of the twist tie and are not released to the atmosphere (CCOF, undated). As previously stated, inert ingredients used in pheromone formulations include compounds that are potentially linked to asthma, cancer, and endocrine disruption (Rose, 2008). Further, exposure to terrestrial organisms and aquatic organisms is expected to be low with dispenser methods, as the dispenser serves as a physical barrier to exposure to the chemicals, and the dispensers can be carefully placed away from water sources (APHIS, 2010a).

As previously mentioned, aerial applications of microencapsulated pheromone formulations may have negative impacts on human health, such as respiratory irritation caused by inhalation of particles. These impacts are not necessarily specific to the pheromone chemicals or inert ingredients in the formulation, but rather are likely due to the size of the microencapsulated product (Cal DPR-OEHHA, 2007). Aerial application methods pose additional ecological risks compared to dispenser methods, for example non-target species such as bees could be coated in the viscous sprayed product while in flight or pick up microcapsules from plant surfaces as they do pollen as discussed previously (Upton et al., 2008). Aerial applications may also result in disposal of product into small streams or water ways, which could potentially impact aquatic ecosystems. However, evaluation of aerial application methods compared to ground application and dispensers found that risk to aquatic systems was slightly higher using twist-tie or ground application methods compared to aerial methods. If twist-ties are applied or ground application occurs close to an aquatic system, the system could be disrupted by the release of pheromones in the general vicinity. Conversely, the fate and transport properties of aerially-applied pheromone formulations make it unlikely for a significant amount of pheromone to actually deposit into an aquatic system (CDFA, 2009).

Evaluation Question #10: Describe and summarize any reported effects upon human health from use of the petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (i), 7 U.S.C. § 6517 (c) (2) (A) (i)) and 7 U.S.C. § 6518 (m) (4)).

Based on low observed toxicity in animal testing, and expected low exposure to humans, no risk to human health is expected from the use of synthetic and nonsynthetic insect pheromones. No effects on human health are reported for any of the pheromone products registered with the EPA. The EPA affirms that during more than ten years of use of synthetic Lepidopteron pheromones as pesticides, no adverse effects have been reported (EPA, 2011).

Many Material Safety Data Sheets for the products referenced in Table 2 note that there is a risk of irritation to the skin and eyes following exposure to the pheromone products. These warnings are in reference to exposures at very high concentrations of the undiluted active ingredient (Suterra, 2012). For passive dispensers, the pheromone is enclosed and diluted within a plastic tube and allowed to dissipate into the atmosphere at low concentrations. Materials used in traps and lures are typically impregnated into a solid material and irritation is not a likely effect of exposure (APHIS, 2010b).

Workers who install, fill, and replace pheromone dispensers may have higher rates of exposure than the general population (APHIS, 2010b). The EPA expects that effects on the endocrine system following long-term exposure would be low due to the chemical properties and metabolism of synthetic pheromones in humans and the lack of effects at a wide range of doses in mammals and other non-target organisms. However, uncertainty surrounds the potential for occupational pheromones exposure to affect the endocrine system, because the EPA does not currently require these types of toxicity studies prior to the registration of pheromone products. Significant data on adverse health effects reported following occupational exposure to pheromones have not been identified and precautionary labeling is required on all products in order to minimize exposure and mitigates risk associated with occupational exposure (EPA, 2001).

An emerging technology is MECs, which consist of small droplets of pheromone enclosed within polymer capsules. The capsules control the release rate of the pheromone into the surrounding environment, and the capsules must be small enough to be applied in the form of a spray. Exposure to these formulations, including any inert ingredients, are presumed to be limited if the pheromone product is applied appropriately. Concern has arisen over the possibility for human inhalation of microcapsules. Inhaled microcapsule particles are more likely to be deposited in nasal passages, the pharynx, the larynx, and the tracheo-bronchial region, where they would then be absorbed into the blood stream or moved to the larynx and subsequently swallowed. Inhalation toxicity studies, designed to examine systemic effects, would not be useful to conduct for pheromone formulations because microcapsule particles are < 25 micrometers in diameter and therefore unlikely to reach the pulmonary region of the lung. Therefore studies of oral toxicity described above are more relevant for considering systemic impacts to human health following inhalation exposure pathways. Studies of oral toxicity described above are therefore relevant for considering systemic impacts to human health following inhalation exposure. It is possible that inhalation of large microcapsule particles could cause irritation of the throat, coughing, sneezing, and upper respiratory mucus production; however, the level of exposure and subsequent potential for irritation is significantly decreased due to the dilution of the product and application spread over a large area (Cal DPR-OEHHA, 2007). However, manufacturers' assert that all microcapsule pheromone formulations are kept above a prescribed diameter to decrease the risk of inhalation by humans (Biddinger and Krawczyk, 2009).

In 2007, CDFA began an emergency eradication program to disrupt mating of the invasive light brown apple moth that had been identified in certain agriculturally-valuable counties. The program began with the placement of pheromone-treated twist-ties on branches, twigs, etc. Growing populations of the light brown apple moth led CDFA to transition to aerial sprays of the synthetic lepidopteran pheromone Checkmate® in September, October, and November (CDFA, 2009). In October, Cal DPR-OEHHA stated that "before the current light brown apple moth eradication effort, DPR had received few complaints involving pheromones, and has no persuasive cases on file attributed to pheromone exposure in the absence of additional pesticides." California EPA did receive email complaints of adverse reactions (upper respiratory symptoms like cough, sore throat, runny nose, congestion; headaches; diarrhea; fatigue) consistent with inhalation of nonspecific irritants following the September spraying; however complaints also included symptoms consistent with infectious and allergic reactions not caused by the pheromone formulation. Cal DPR-OEHHA concluded in their statement issued October 31, 2007 that while exposure to high levels of Checkmate might produce symptoms consistent with many of those reported, the application level was extremely low and exposure levels were below what was expected to cause human health effects (Cal DPR-OEHHA, 2007).

However, in September, October, and November of 2007, more than 643 health complaints were recorded associated with aerial spraying of Checkmate® in Monterey and Santa Clara counties; these included the aforementioned upper respiratory symptoms as well as a variety of cardiopulmonary reactions such as arrhythmia, tachycardia, and chest pain, menstrual irregularities, blurred vision, sinus bleeding, and severe skin rashes (Rose, 2008).

The Environmental Assessment of the Light Brown Apple Moth Program in California conducted by APHIS concluded that the light brown apple moth pheromone was unlikely to cause any effects to humans based on low toxicity (APHIS, 2010a). During this eradication program, aerial spraying was conducted for several months followed by the use of passive dispensers throughout the application area. The impact on human health from aerial spraying was not addressed in detail and a thorough analysis on the effects to human health following significant exposure pheromones applied using aerial application could not be identified. When the pheromone application method was a dispenser system in which the pheromone was suspended within a plastic casing clipped to a tree, shrub, or stick, and slowly released over several weeks or months, human exposure to the pheromone chemical was expected to be minimal (APHIS, 2010a). APHIS reported that bioaccumulation and persistence of straight chain lepidopteran pheromones in humans was not expected, as the pheromones are structurally similar to food items and will be metabolized. The authors noted that the gypsy moth pheromone, disparlure, can persist in the human body for many years; however, the only known side effect is the attraction of gypsy moths, which was observed in one occupational exposure case (APHIS, 2010b).

Evaluation Question #11: Describe all natural (nonsynthetic) substances or products which may be used in place of a petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (ii)). Provide a list of allowed substances that may be used in place of the petitioned substance (7 U.S.C. § 6518 (m) (6)).

Pheromones generally are used as an alternative to chemical pesticides for controlling populations of insect pests. Commercially available pheromones are considered synthetic, but when isolated directly from a target insect species are considered to be nonsynthetic. As pheromone substances are extremely specific, alternative substances would have to mirror the complexity and specificity of pheromones. While no nonsynthetic substances or products have been identified for use in place of nonsynthetic or synthetic pheromone products, there are commercially available nonsynthetic products that can aid in pest management. These products are described below.

Nonsynthetic oils derived from animal or plant sources have been observed to be effective in controlling pest populations. For example, neem oil is a non-synthetic pressed vegetable oil that is created from the fruits and seeds of an evergreen tree and is effective in the control of a variety of mite populations (Gegner, 2003). Some OMRI listed products containing nonsynthetic oils as the primary active ingredient are provided below (OMRI, 2012):

- Bayer Advanced Natria™ Multi-Insect Control Concentrate: Bayer Advanced, 2TW Alexander Drive, Research Triangle Park, NC 27709.
- Bayer Advanced Natria™ Multi-Insect Control Ready-to-Spray: Bayer Advanced, 2TW Alexander Drive, Research Triangle Park, NC 27709.
- Golden Pest Spray Oil™: Stoller Enterprises, Inc., 4001 W. Sam Houston Pkwy. N., Suite 100, Houston, TX 77043.
- EcoLogic Pro™ Blaze™: Marrone Bio Innovations, 2121 Second St. Suite 107B Davis, CA 95618.

Bacillus thuringiensis (Bt) is a naturally occurring bacterial disease of insects. These bacteria are the active ingredient in some insecticides that are used in the control of some needle- and leaf-feeding caterpillars as well as the larvae of leaf beetles and certain fly larvae. Currently, Bt is the only microbial insecticide used for wide scale application. This microbial insecticide acts by producing a protein, delta-endotoxin, which reacts with the cells of the gut lining of insects. These proteins then paralyze the digestive system, causing the insect to stop feeding within hours. The affected insects typically die from starvation within several days of exposure to Bt (Cranshaw, 2008).

In addition, section 205.601(e) lists synthetic substances that are allowed for use as insecticides in organic crop production. These materials include lime sulfur, elemental sulfur, soaps, horticultural oils (narrow range oils as dormant, suffocating, and summer oils), sucrose octanoate esters (CAS #s—42922–74–7; 58064–47–4), and sticky traps and barriers (7 CFR 205.601(e)).

Evaluation Question #12: Describe any alternative practices that would make the use of the petitioned substance unnecessary (7 U.S.C. § 6518 (m) (6)).

The NOP regulations (specifically 7 CFR 205.206(a) and 205.206(b)) identify pest management practices compatible with organic crop production, including:

- Augmentation or introduction of predators or parasites of the pest species;
- Development of habitat for natural enemies of pests;
- Nonsynthetic controls such as lures, traps, and repellents;
- Crop rotation and soil and crop nutrient management practices;
- Sanitation measures to remove disease vectors, weed seeds, and habitat for pest organisms; and
- Cultural practices that enhance crop health, including selection of plant species and varieties with regard to suitability to site-specific conditions and resistance to prevalent pests, weeds, and diseases.

In addition, the National List specifically permits the used of synthetic sticky traps/barriers for insect control (7 CFR 205.601(e)(8)). Additional descriptions of available pest control practices are provided below.

- Netting (e.g., cheese cloth) can be used to protect seedlings from chewing insect pests and prevent flying insects from laying eggs on emerging plants (Waters, 2011).

- Collars, or barriers that fit tightly around the stem of a plant, can be used to stop hatching larvae from burrowing into the soil surrounding plants. A collar is made of stiff paper, heavy plastic, or tar paper (Waters, 2011).

- Pests, larvae, or egg masses can be removed by hand.

- A coffee can trap can be used by burying a tin can in the soil bed so that the outer edge of the can is level with the soil surface. Insects fall into the trap and cannot get out. This trap also collects beneficial insects and may be used to monitor the insect population in a particular growing area (Waters, 2011).

- Alternative crop planting methods can be used to reduce agricultural insect pests. One example of such a practice is trap cropping, which involves planting a separate crop that is more attractive to a particular pest. There are two types trap cropping: row intercropping and perimeter trap cropping. Perimeter trap cropping (border trap cropping) involves planting a trap crop completely surrounding the main cash crop in order to prevent pests from entering all sides of the field. Row intercropping is the practice of planting a trap crop in alternating rows with the main crop. Other planting practices like crop rotation and polyculture (agriculture using multiple crops in the same space) can also assist in managing and controlling pests (PAN Germany, 2005).

- Introduction of beneficial insects can help reduce the population of insect pests. Some examples include ladybugs, bees, praying mantises, dragonflies, green lacewings, and predacious mites, wasps, and spiders (Waters, 2011).

References:

APHIS, 2010a. Use of LBAM Mating Disruption Pheromone Dispenser in the Light Brown Apple Moth Program in California: Environmental Assessment. Retrieved September 14, 2011 from http://www.aphis.usda.gov/plant_health/ea/downloads/lbam-twist-tie-ea.pdf

APHIS, 2010b. Response to Comments on the Use of Light Brown Apple Moth Mating Disruption Pheromone Dispensers in the Light Brown Apple Moth Program in California, Environmental Assessment, September 2010. Retrieved July 18, 2011 from http://www.aphis.usda.gov/plant_health/ea/downloads/lbam-twist-tie-ea-comments.pdf

Baldwin, R., 2011. Pheromones. Retrieved June 16, 2011 from http://entomology.ifas.ufl.edu/baldwin/webbugs/pest2/content/13/13_handout.pdf

Biddinger, D. and Krawczyk, G., 2009. Pheromone Mating Disruption for Conventional and Organic Orchards. Retrieved June 21, 2011 from http://extension.psu.edu/ipm/resources/nrcs/programs/treefruit/pheromonemating

Bloomquist, G.J. and Vogt, R.G., 2003. Insect pheromone biochemistry and molecular biology: The biosynthesis and detection of pheromones and plant volatiles. Retrieved March 19, 2012 from http://books.google.com/books?id=YMoiaNboEzAC&printsec=frontcover#v=onepage&q&f=false

Cal DPR-OEHHA (California Department of Pesticide Regulation and the Office of Environmental Health Hazard Assessment). 2007. Consensus Statement on Human Health Aspects of the Aerial Application of Microencapsulated Pheromones to Combat the Light Broth Apple Moth. October 31, 2007. Available online at http://www.cdfa.ca.gov/plant/pdep/lbam/pdfs/FactSheets/Consensus_Statement_on_Human_Health_Aspects.pdf

California LBAM Eradication Plan. 2008. Pheromone Search of 942 Monterey County Lepidoptera Species: Potentially Affected Non-Target Species. Search dated 10-06-07; Revised 2-13-08. Report #37, LBAM Spray Info. Available online at http://www.lbamspray.com/Reports.htm

Canadian General Standards Board, 2011. Retrieved August 16, 2011 from http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/internet/bio-org/documents/032-0311-2008-eng.pdf

Carter, N., 2003. Mating Disruption for Management of Insect Pests; Factsheet. Retrieved July 5, 2001, from http://www.omafra.gov.on.ca/english/crops/facts/03-079.htm#howdoes

CBC, 2011. Pheromones and Mating Disruption. Retrieved June 21, 2011 from http://www.cbc-europe.it/images/stories/file/biocontrol/GuidaBioENG.pdf

CCOF (California Certified Organic Farmers), undated. CCOF Organic Management of the Light Brown Apple Moth (LBAM). Retrieved March 27, 2012 from http://www.ccof.org/pdf/OrganicIPMforLBAMfinal.pdf

CDFA (California Department of Food and Agriculture). 2009. LBAM Programmatic Environmental Impact Report (PEIR). Available online at http://www.cdfa.ca.gov/plant/PDEP/lbam/envimpactrpt.html

Clark, J., 2004. An introduction to esters. Retrieved June 21, 2011 from http://www.chemguide.co.uk/organicprops/esters/background.html

Chiras, D., 2010. Environmental Science, 8th edition. Retrieved June 23, 2011 from http://books.google.com/books?id=L28bHnPXo1AC&pg=PA510&lpg=PA510&dq=insect+pheromones+and+persistence+in+the+environment&source=bl&ots=FS0UuZKNWx&sig=ygm3ldsA3XvG63hvpJsLNoHvKus&hl=en&ei=fUYDTo_HII6u0AHe7JHeDQ&sa=X&oi=book_result&ct=result&resnum=3&ved=0CCoQ6AEwAg#v=onepage&q=insect%20pheromones%20and%20persistence%20in%20the%20environment&f=false

CODEX Alimentarius Commission, 2001. Guideline for the Production, Processing, Labeling, and Marketing of Organically Produced Foods. Retrieved June 16, 2011 from http://www.codexalimentarius.net/web/standard_list.do?lang=en

Cranshaw, W.S., 2008. Colorado State University Fact Sheet: *Bacillus thuringiensis*. Retrieved September 12, 2011 from http://www.ext.colostate.edu/pubs/insect/05556.html

EPA, 2001. Straight chain Lepidopteran Pheromones Biopesticide Registration Action Document. Retrieved June 23, 2011 from http://www.epa.gov/oppbppd1/biopesticides/ingredients/tech_docs/brad_129109.pdf

EPA, 2010. Pesticide Registration Manual: Chapter 3 - Additional Considerations for Biopesticide Products. Retrieved June 23, 2011 from http://www.epa.gov/opprd001/registrationmanual/chapter3.html#pheromone

EPA, 2011. Lepidopteran Pheromones Fact Sheet. Retrieved March 16, 2012 from http://www.epa.gov/oppbppd1/biopesticides/ingredients/factsheets/factsheet_lep_pheromones.htm

European Economic Community 2008. Commission Regulation (EC) No 889/2008. Retrieved March 26, 2012 from http://eur-lex.europa.eu/JOHtml.do?uri=OJ:L:2008:250:SOM:EN:HTML

Gegner, L., 2003. Beekeeping/Apiculture, Retrieved February 15, 2011 from http://attra.ncat.org/attra-pub/beekeeping.html#tracheal

ISCA Technologies, 2010. SPLAT. Retrieved March 19, 2012 from http://www.iscatech.com/exec/SPLAT.htm

Krieger, I., 2001. Handbook of Pesticide Toxicology: Principles. Retrieved June 16, 2011 from http://books.google.com/books?id=ib8Qhju9EQEC&pg=PA141&lpg=PA141&dq=mode+of+action+for+pheromone&source=bl&ots=DfAwl6Ftoh&sig=GUIqJOrXsBmGWKcFO9Zm92-3HGI&hl=en&ei=CIL6TZHfNPKv0AG-gMGqAw&sa=X&oi=book_result&ct=result&resnum=9&ved=0CEEQ6AEwCA#v=onepage&q=mode%20of%20action%20for%20pheromone&f=false

Miller, J.R., Gut, L.J., de Lame, F.M., and Stelinski, L.L., 2006. Differentiation of Competitive vs. Non-competitive Mechanisms Mediating Disruption of Moth Sexual Communication by Point Sources of Sex Pheromone (Part I): Theory. Journal of Chemical Ecology, 32: 2089-2114. Retrieved March 19, 2012 from https://www.msu.edu/~stelinsk/Miller%20et%20al%20JCE.pdf

Mori, K., 2010. Chemical Synthesis of Hormones, Pheromones, and Other Bioregulators. Retrieved June 21, 2011 from http://books.google.com/books?id=fSwwYyZMDBoC&printsec=frontcover&dq=synthesis+pheromone&hl=en&ei=57wATu3pMoOutwfY_cCmDg&sa=X&oi=book_result&ct=result&resnum=1&ved=0CDMQ6AEwAA#v=onepage&q=synthesis%20pheromone&f=false

Muir, P., 2001. Oregon State University: Chemical Controls. Retrieved June 2, 2011 from http://people.oregonstate.edu/~muirp/chemcont.htm

National Pesticide Information Retrieval System (NPIRS), 2012. Pesticide Products. Retrieved March 23, 2012 from http://ppis.ceris.purdue.edu/htbin/ppisprod.com

NOSB, 2011a. Formal Recommendation by the NOSB to the National Organic Program. Retrieved March 9, 2012 from http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5091711

NOSB, 2011b. Inert Ingredients Discussion Document, dated October 11, 2011, Retrieved March 13, 2012 from http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5094901

O' Leary, D., 2000. Alkenes Chemical Properties. Retrieved June 16, 2011 from http://www.ucc.ie/academic/chem/dolchem/html/dict/alkenes.html

OMRI, 2011. Out of Scope and Beyond Resolution: Passive Pheromone Dispensers. Retrieved September 9, 2011 from http://www.omri.org/suppliers/OMRIscope

OMRI, 2012. Products List. Retrieved September 9, 2011 from http://www.omri.org/sites/default/files/opl_pdf/crops_category.pdf

PAN Germany, 2005. Trap cropping. Retrieved June 23, 2011 from http://www.oisat.org/control_methods/cultural__practices/trap_cropping.html

Pest Management Regulatory Agency (PMRA), 2010. PMRA List of Formulants. Retrieved March 19, 2012 from http://publications.gc.ca/collections/collection_2010/arla-pmra/H114-22-2010-eng.pdf

Pherobase, 2012. Database of pheromones and semiochemicals. Retrieved March 23, 2012 from http://pherobase.com/

Pimentel, D., 2007. Encyclopedia of Pest Management, Volume 2. CRC Press, Boca Raton, FL. Retrieved March 19, 2012 from http://books.google.com/books?id=DxrMm9lMFUAC&pg=PA67&dq=Encyclopedia+of+Agrochemicals&hl=en&sa=X&ei=fVZnT4LzNKOh0QWzgqCgCA&ved=0CEQQ6AEwBA#v=onepage&q=pheromone&f=false

Regnier, F. E. and Law, J. H., 1968. Insect pheromones. Journal of Lipid Research, Vol. 9. Retrieved June 15, 2011 from http://www.ncbi.nlm.nih.gov/pubmed/4882034

Resh, V.H. and Cardé, R.T., 2009. Encyclopedia of Insects. Elseiver, Inc., Burlington, MA. Retrieved March 19, 2012 from http://books.google.com/books?id=Jk0Hym1yF0cC&printsec=frontcover&dq=The+Encyclopedia+of+Insects&hl=en&sa=X&ei=4HBnT7nMJ8-3hAfZ5LCzCA&ved=0CD8Q6AEwAA#v=onepage&q=moth%20pheromone&f=false

Rose, L. 2008. Marin Pesticide Spraying Health Hazard Alert. Report #30, LBAM Spray Info. Available online at http://www.lbamspray.com/Reports.htm

Seybold, S. and Donaldson, S., 1998. Pheromones in Insect Pest Management. Retrieved June 20, 2011 from http://www.unce.unr.edu/publications/files/ag/other/fs9841.pdf

Suterra, LLC, 2012. Labels/MSDS. Retrieved March 26, 2012 from http://www.cdms.net/LabelsMsds/LMDefault.aspx?manuf=187&t=

Upton, R., Harder, D., Dadant, T. 2008. Light Brown Apple Moth (LBAM) Eradication Program: Potential Effects on Pollinators and Implicatiosn for Califonia Agriculture. Summary Report, LBAM Fact Sheet: EPB 1.3. Available online at http://www.lbamspray.com/Reports/Bees.pdf

Waters, A., 2011. Alternatives to Pesticides. Retrieved June 27, 2011 from http://www.state.nj.us/dep/enforcement/pcp/administration/alternative.pdf

Welter, S., Pickel, C., Millar, J., Cave, F., Van Steenwyk, R.A., and Dunley, J., 2005a. Pheromone mating disruption offers selective management options for key pests. California Agriculture, 59(1): 16-22. Retrieved March 9, 2012 from http://ucanr.org/repository/cao/landingpage.cfm?article=ca.v059n01p16&fulltext=yes

Welter, S., Casado, D., Cave, F., Elkins, R., Grant, J., and Pickel, C., 2005b. Why puffers work: determining the effects of residual releases on control of codling moth. Retrieved June 10, 2011 from www.calpear.com/_pdf/research-reports/Why%20Puffers%20Work.pdf

Witzgall, P., 2001. Pheromones- future techniques for insect control. Pheromones for Insect Control in Orchards and Vineyards, Vol. 24(2): 114-122. Retrieved June 21, 2011 from http://phero.net/iobc/hohenheim/bulletin/witzgall.pdf

Appendix A. Partial List of Commercially Available Pheromone Products that are Registered by the EPA

Product Name	Manufacturer	Chemical Name of Pheromone(s) (Active Ingredients)	CAS No.	Intended Use and Target Organism	Delivery/Application Method	EPA Reg. No.
Technical pheromones for use in manufacturing and formulating of an end use product (i.e., for use in a pheromone delivery product)						
N-tetradecyl acetate technical pheromone	BASF Corp.	Myristyl acetate	638-59-5	For use in combination with straight chain lepidopteran pheromones used in mating disruption for control of codling moth	Hand-placed, retrievable pheromone dispensers used	7969-282
Oriental fruit moth technical pheromone	Shin-etsu Chemical Co., Ltd.	(Z)-8-Dodecen-1-yl acetate; (E)-8-Dodecen-1-yl acetate; Z-8-DDOL	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth, Macadamia Nut Borer, and Koa Seed Worm	Dispensers	47265-1
Codling moth technical pheromone	Shin-etsu Chemical Co., Ltd.	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth and hickory shuckworm	Dispensers	47265-2
Z-11-tetradecenyl acetate technical pheromone	Shin-etsu Chemical Co., Ltd.	(Z)-11-Tetradecenyl acetate	20711-10-8	Mating disruption for control of the leafroller moth	Dispensers	47265-3
E-11/Z-11-tetradecenyl acetate technical pheromone	Shin-etsu Chemical Co., Ltd.	(Z)-11-Tetradecenyl acetate; 11-Tetradecen-1-ol, acetate, (E)-	20711-10-8; 33189-72-9	Mating disruption for control of the leafroller moth	Dispensers	47265-5
Pink boll worm pheromone technical	Mitsubishi International Corp	(Z,E)-7,11-Hexadecadien-1-yl acetate; (Z,Z)-7,11-Hexadecadien-1-yl acetate	53042-79-8; 52207-99-5	Mating disruption for control of the pink boll worm	Dispensers	50675-2
Trece Japanese beetle pheromone-technical-Manufacturing Use	Trece, Inc.	(R,Z)-5-(1-Decenyl)dihydro-2(3H)-furanone	64726-91-6	For use in formulating baits used to trap Japanese Beetles	Baits (used in pheromone traps)	51934-4
Bedoukian OFM Technical Pheromone	Bedoukian Research Inc.	(Z)-8-Dodecen-1-yl acetate; (E)-8-Dodecen-1-yl acetate; Z-8-DDOL	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth	Not specified	52991-1
Bedoukian High Purity CM Pheromone	Bedoukian Research Inc.	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth	Not specified	52991-2
Bedoukian TPW Technical Pheromone	Bedoukian Research Inc.	(Z)-4-Tridecen-1-yl acetate; (E)-4-Tridecen-l-yl acetate	65954-19-0; 72269-48-8	Mating disruption for control of the tomato pinworm	Not specified	52991-3
Bedoukian Z-9-Tricosene Technical Pheromone	Bedoukian Research Inc.	Muscalure, component of (with 103202)	27519-02-4	Mating disruption for control of the house fly	Not specified	52991-4
Bedoukian PTB Technical Pheromone	Bedoukian Research Inc.	(E)-5-Decen-1-ol ; 5-Decen-1-ol, acetate, (E)-	56578-18-8; 38421-90-8	Mating disruption for control of the peach twig borer	Not specified	52991-6
Bedoukian 11-	Bedoukian Research	11-Tetradecen-1-ol, acetate,	33189-72-9	Mating disruption for control of the	Not specified	52991-8

Product Name	Manufacturer	Chemical Name of Pheromone(s) (Active Ingredients)	CAS No.	Intended Use and Target Organism	Delivery/Application Method	EPA Reg. No.
Tetradecenyl Acetate Technical Pheromone	Inc.	(E)-		European corn borer as well as other Lepidoptera		
Bedoukian 9-Dodecenyl Acetate Technical Pheromone	Bedoukian Research Inc.	9-Dodecenyl acetate, (Z)-	16974-11-1	Mating disruption for control of the Western pine shootborer as well as other Lepidoptera	Not specified	52991-10
Bedoukian NOW Technical Pheromone	Bedoukian Research Inc.	Navel orangeworm pheromone	71317-73-2	Mating disruption for control of the navel orangeworm	Not specified	52991-11
Technical Codling Moth Pheromone	Bedoukian Research Inc.	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth	Not specified	52991-12
Bedoukian (Z)-11-Hexadecenal Technical Pheromone	Bedoukian Research Inc.	(Z)-11-Hexadecenal	53939-28-9	Mating disruption for control of the Diamondback moth as well as other Lepidoptera	Not specified	52991-14
Bedoukian (Z)-11-Hexadecenyl Acetate Technical Pheromone	Bedoukian Research Inc.	(Z)-11-Hexadecenyl acetate	34010-21-4	Mating disruption for control of the Diamondback moth as well as other Lepidoptera	Not specified	52991-15
Bedoukian (Z)-6-Heneicosen-11-One Technical Pheromone	Bedoukian Research Inc.	6-Heneicosen-11-one, (6Z)-	54844-65-4	Mating disruption for control of the Douglas fir tussock moth	Not specified	52991-17
Bedoukian Indian Meal Moth Technical Pheromone	Bedoukian Research Inc.	(Z,E)-9,12-Tetradecadienyl acetate	30507-70-1	Mating disruption for control of the Indian meal moth, Mediterranean flour moth, tobacco moth, raisin moth, almond moth, and beet armyworm	Not specified	52991-18
Bedoukian E, E-9,11-Tetradecadienyl Acetate Technical Pheromone	Bedoukian Research Inc.	9,11-Tetradecadien-1-ol, acetate, (9E, 11E)-	54664-98-1	Mating disruption for control of the light brown apple moth	Not specified	52991-22
Materia PTB Technical Pheromone	Materia, Inc.	(E)-5-Decen-1-ol; 5-Decen-1-ol, acetate, (E)-	56578-18-8; 38421-90-8	Mating disruption for control of the peach tree boarer	Not specified	74395-1
Bioglobal Codling Moth Technical Pheromone	Bioglobal Ltd.	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth	Not specified	82794-1
Biological Oriental Fruit Moth Technical Pheromone	Bioglobal Ltd.	(Z)-8-Dodecen-1-yl acetate; (E)-8-Dodecen-1-yl acetate; Z-8-DDOL	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth	Not specified	82794-2

Product Name	Manufacturer	Chemical Name of Pheromone(s) (Active Ingredients)	CAS No.	Intended Use and Target Organism	Delivery/Application Method	EPA Reg. No.
Checkmate® CM Technical Pheromone II	Suterra, LLC CP Pheromones	(E,E)-8,10-dodecadien-l-ol	33956-49-9	Mating disruption for control of the codling moth; attractant for monitoring	Not specified	56336-60
Checkmate ®NOW Technical Pheromone	Suterra, LLC CP Pheromones	Navel orangeworm pheromone	71317-73-2	Mating disruption for control of the navel orangworm; attractant for monitoring	Not specified	56336-62
Certis Technical Olive Fly Pheromone	Suterra, LLC CP Pheromones	1,7-Dioxaspiro[5.5] undecane	180-84-7	Mating disruption for control of the olive fly	Not specified	56336-52
Checkmate® WPCM Technical Pheromone	Suterra, LLC CP Pheromones	E,Z-3,13-Octadecadien-1-ol; (Z,Z)-3, 13-Octadecadien-1-ol	66410-24-0; 66410-28-4	Mating disruption for control of the Western poplar clearwing moth; attractant for monitoring	Not specified	56336-48
Checkmate® OFM Technical Pheromone	Suterra, LLC CP Pheromones	Z)-8-Dodecen-l-yl Acetate; (E)-8-Dodecen-l-yl Acetate; (Z)-8-Dodecen-l-ol	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth; attractant for monitoring	Not specified	56336-2
Checkmate® CM Technical Pheromone	Suterra, LLC CP Pheromones	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth; attractant for monitoring	Not specified	56336-4
CheckMate® PTB Technical Pheromone	Suterra, LLC CP Pheromones	(E)-5-Decen-1-ol; 5-Decen-1-ol, acetate, (E)-	56578-18-8; 38421-90-8	Mating disruption for control of the peach twig borer	Not specified	56336-15
CheckMate® TPW Technical Pheromone	Suterra, LLC CP Pheromones	(Z)-4-Tridecen-1-yl acetate; (E)-4-Tridecen-l-yl acetate	65954-19-0; 72269-48-8	Mating disruption for control of the tomato pinworm; attractant for monitoring	Not specified	56336-6
Checkmate® BAW Technical Pheromone	Suterra, LLC CP Pheromones	(Z,E)-9,12-Tetradecadienyl acetate	30507-70-1	Mating disruption for control of the beet armyworm and the Indian meal moth; attractant for monitoring	Not specified	56336-47
Checkmate® VMB Technical Pheromone	Suterra, LLC CP Pheromones	Lavandulyl senecioate	23960-07-8	Mating disruption for control of the vine mealybug moth; attractant for monitoring	Not specified	56336-55
Isomate® P Pheromone	Pacific Biocontrol Corp.	(Z,Z)-3,13-Octadecadien-1-ol acetate; (E,Z)-3,13-Octadecadien-1-ol acetate	53120-27-7; 53120-26-6	Mating disruption for control of the greater peachtree borer	Not specified	53575-17
Puffers						
Checkmate® CM Puffer Dispenser	Suterra, LLC	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth and hickory shuckworm moth	Puffer	56336-34
Puffer APM	Suterra, LLC	(Z)-11-Hexadecenal	53939-28-9	Mating disruption for control of the artichoke plume moth	Puffer	56336-45
Puffer CM	Suterra, LLC	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth in apple, pear, and walnut orchards	Puffer	74379-2
Puffer OFM	Suterra, LLC	(Z)-8-Dodecen-1-yl acetate; (E)-8-Dodecen-1-yl acetate; Z-8-DDOL	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth in almond, apple, apricot, cherry, nectarine, peach, pear, plum, prune,	Puffer	73479-8

Product Name	Manufacturer	Chemical Name of Pheromone(s) (Active Ingredients)	CAS No.	Intended Use and Target Organism	Delivery/Application Method	EPA Reg. No.
				and quince orchards		
Puffer CM/O	Suterra, LLC	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth in apple, pear, and walnut orchards	Puffer	73479-9
Puffer OFM/O	Suterra, LLC	(Z)-8-Dodecen-1-yl acetate; (E)-8-Dodecen-1-yl acetate; Z-8-DDOL	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth in almond, apple, apricot, cherry, nectarine, peach, pear, plum, prune, and quince orchards	Puffer	73479-10
Checkmate® Puffer CM/OFM	Suterra, LLC	(Z)-8-Dodecen-1-yl acetate; (E)-8-Dodecen-1-yl acetate; Z-8-DDOL; (E,E)-8,10-Dodecadien-1-ol	28079-04-1; 38363-29-0; 40642-40-8; 33956-49-9	Mating disruption for control of the codling moth and oriental fruit moth in apple, pear, peach, nectarine and any other crops where the oriental fruit moth and codling moth are overlapping problems	Puffer	73479-11
Specialized Pheromone and Lure Application Technology (SPLAT)						
SPLAT-MAT Spinosad ME	Dow Agrosciences	Spinosad (Naturally occurring mixture of spinosyn A and spinosyn D); methyl eugenol	131929-60-7; 93-15-2	For selective attraction and control of male tephritid fruit flies of the genus *Bactrocera* (or other fruit fly species which respond to the male specific attractant methyl eugenol)	Biocidal bait	62719-592
SPLAT OFM 30M-1	ISCA Technologies	(Z)-8-Dodecen-1-yl acetate ; (E)-8-Dodecen-1-yl acetate ; Z-8-DDOL	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth	Amorphous polymer matrix for the sustained passive release of insect pheromones	80286-1
SPLAT PBW 30M-1	ISCA Technologies	(Z,E)-7,11-Hexadecadien-1-yl acetate; (Z,Z)-7,11-Hexadecadien-1-yl acetate	53042-79-8; 52207-99-5	Mating disruption for control of the oriental fruit moth	Amorphous polymer matrix for the sustained passive release of insect pheromones	80286-2
SPLAT GM	ISCA Technologies	cis-7,8-Epoxy-2-methyloctadecane	29804-22-6	Mating disruption for control of the gypsy moth	Amorphous polymer matrix for the sustained passive release of insect pheromones	80286-4
SPLAT GBM	ISCA Technologies	9-Dodecenyl acetate, (Z)-; 9-Tetradecen-1-ol, acetate	16974-11-1; N/A	Mating disruption for control of grape berry moth	Amorphous polymer matrix for the sustained passive release of insect pheromones	80286-5
SPLAT LBAM HD	ISCA Technologies	9,11-Tetradecadien-1-ol, acetate, (9E, 11E)- ; 11-Tetradecen-1-ol, acetate, (E)-	54664-98-1; 33189-72-9	Mating disruption for control of light brown apple moth	Amorphous polymer matrix for the sustained passive release of insect pheromones	80286-6
SPLAT LBAM LD	ISCA Technologies	9,11-Tetradecadien-1-ol, acetate, (9E, 11E)-; 11-Tetradecen-1-ol, acetate, (E)-	54664-98-1; 33189-72-9	Mating disruption for control of light brown apple moth	Amorphous polymer matrix for the sustained passive release of insect pheromones	80286-8
SPLAT CYDIA V2	ISCA Technologies	Dodecyl alcohol; Tetradecyl alcohol; (E,E)-8,10-	33956-49-9; 112-72-1	Mating disruption for control of codling moth and hickory shuckworm	Amorphous polymer matrix for the sustained	80286-11

Product Name	Manufacturer	Chemical Name of Pheromone(s) (Active Ingredients)	CAS No.	Intended Use and Target Organism	Delivery/Application Method	EPA Reg. No.
		Dodecadien-1-ol			passive release of insect pheromones	
SPLAT GM-O	ISCA Technologies	cis-7,8-Epoxy-2-methyloctadecane	29804-22-6	Mating disruption for control of the gypsy moth	Amorphous polymer matrix for the sustained passive release of insect pheromones	80286-12
SPLAT LBAM HD-O	ISCA Technologies	9,11-Tetradecadien-1-ol, acetate, (9E, 11E)-; 11-Tetradecen-1-ol, acetate, (E)-	20711-10-8; 33189-72-9	Mating disruption for control of the light brown apple moth	Amorphous polymer matrix for the sustained passive release of insect pheromones	80286-13
SPLAT CLM	ISCA Technologies	Citrus leafminer lepidoptera pheromone (7,11,13-Hexadecatrienal, (7Z,11Z,13E)-)	N/A	Mating disruption for control of the citrus leafminer	Amorphous polymer matrix for the sustained passive release of insect pheromones	80286-15
SPLAT TUTA	ISCA Technologies	(E,Z,Z)-3,8,11-Tetradecatrienyl acetate	163041-94-9	Mating disruption for control of the tomato leafminer	Amorphous polymer matrix for the sustained passive release of insect pheromones	80286-16
Dispensers (e.g., rings, spirals, etc.)						
Isomate® - CM RING	Pacific Biocontrol Corp.	(E, E)-8, 10-Dodecadien-1-ol; 1-Dodecanol; 1-Tetradecanol	33956-49-9; 112-53-8; 112-72-1	Mating disruption for control of the codling moth and hickory shuckworm	Dispenser	53575-35
Isomate® - OFM RING	Pacific Biocontrol Corp.	(Z)-8-Dodecen-1-yl acetate; (E)-8-Dodecen-1-yl acetate; Z-8-DDOL	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth, macadamia nut borer, koa seedworm	Dispenser	55375-39
NoMate® TPW Spiral	Scentry Biologicals, Inc.	(Z)-4-Tridecen-1-yl acetate; (E)-4-Tridecen-l-yl acetate	65954-19-0; 72269-48-8	Mating disruption for control of the tomato pinworm	Dispenser	36638-27
NoMate® CM Spiral	Scentry Biologicals, Inc.	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth	Dispenser	36638-30
NoMate® OLR Spiral	Scentry Biologicals, Inc.	(Z)-11-Tetradecenyl acetate; 11-Tetradecen-1-ol, acetate, (E)-	20711-10-8; 33189-72-9	Mating disruption for control of the ominovorous leaf roller	Dispenser	36638-31
NoMate® OFM Spiral	Scentry Biologicals, Inc.	(Z)-8-Dodecen-1-yl acetate; (E)-8-Dodecen-1-yl acetate; Z-8-DDOL	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth	Dispenser	36638-33
NoMate® PTB Spiral	Scentry Biologicals, Inc.	(E)-5-Decen-1-ol; 5-Decen-1-ol, acetate, (E)-	56578-18-8; 38421-90-8	Mating disruption for control of the PeachTwig Borer	Dispenser	36638-38
NoMate® LBAM Spiral	Scentry Biologicals, Inc.	9,11-Tetradecadien-1-ol, acetate, (9E, 11E)- ; 11-Tetradecen-1-ol, acetate, (E)-	54664-98-1; 33189-72-9	Mating disruption for control of the light brown apple moth	Dispenser	36638-43
Isomate® - OBLR/PLR Plus	Pacific Biocontrol Corp.	Z-11-Tetradecen-1-yl Acetate	20711-10-8	Mating disruption for control of the obliquebanded leafroller and pandemis leafroller	Dispenser	53575-24

Product Name	Manufacturer	Chemical Name of Pheromone(s) (Active Ingredients)	CAS No.	Intended Use and Target Organism	Delivery/Application Method	EPA Reg. No.
Isomate® - M 100	Pacific Biocontrol Corp.	(Z)-8-Dodecen-1-yl acetate; (E)-8-Dodecen-1-yl acetate ; Z-8-DDOL	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth, macadamia nut borer, and koa seedworm	Dispenser	53575-19
Isomate® - LBAM Plus	Pacific Biocontrol Corp.	(E)-11-Tetradecenyl Acetate; (E,E)-9,ll-Tetradecadienyl Acetate	33189-72-9; 30562-09-5	Mating disruption for control of the light brown apple moth	Dispenser	53575-33
Isomate® - PTB Dual	Pacific Biocontrol Corp.	(E.Z)-3,13 Octadecadien-1-yl Acetate; (Z.Z)-3,13 Octadecadien-.1-yl Acetate	N/A	Mating disruption for control of the lesser peachtree borer and greater peachtree borer	Dispenser	53575-34
Isomate® - CM/ LR TT	Pacific Biocontrol Corp.	Dodecyl alcohol ; Tetradecyl alcohol; 11-Tetradecenal, (11Z)-; (Z)-11-Tetradecenyl acetate; 11-Tetradecen-1-ol, (Z)-; (E,E)-8,10-Dodecadien-1-ol; 9-Tetradecen-1-ol, acetate, (9Z)	112-53-8; 112-72-1; 35237-64-0; 20711-10-8; 34010-15-6; 33956-49-9; 16725-53-4	Mating disruption for control of the codling moth, obliquebanded leafroller, pandemic leafroller, fruittree leafroller, threelined leafroller, and European leafroller	Dispenser	53575-31
Isomate® - DWB	Pacific Biocontrol Corp.	(Z,Z)-3,13-Octadecadien-1-yl Acetate; (E,Z)-2,13-Octadecadien-1-yl Acetate; (Z,Z)-3,1 3-Octadecadien-1 –ol; (E,Z)-2,13-Octadecadien-1-ol	53120-27-7; 86252-65-5; 66410-24-0; 123551-47-3	Mating disruption for control of the dogwood borer	Dispenser	53575-40
Isomate® - GRB	Pacific Biocontrol Corp.	(E,Z)-2,13-Octadecadien-1-yl Acetate; (E,Z)-3,13-Octadecadien-1-yl Acetate	86252-65-5; 53120-27-7	Mating disruption for control of the graperoot borer and currant borer	Dispenser	53575-41
Breeze CM Pheromone	BASF Corp.	Myristyl acetate; (E,E)-8,10-Dodecadien-1-ol	638-59-5; 33956-49-9	Mating disruption for control of the codling moth and hickory shuckworm	Dispenser	7969-286
CheckMate® CM Hand applied dispenser	Suterra, LLC CP Pheromones	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth	Dispenser	56336-5
CheckMate® CM 180/1-P Dispenser	Suterra, LLC CP Pheromones	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth and hickory shuckworm.	Dispenser	56336-13
CheckMate® OFM XL	Suterra, LLC CP Pheromones	(Z)-8-Dodecen-1-yl acetate; (E)-8-Dodecen-1-yl acetate; (Z)-8-Dodecen-1-01	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth, macadamia nut borer, and koa seedworm	Dispenser	56336-36
CheckMate® SPM Dispenser	Suterra, LLC CP Pheromones	(Z,E)-9, 12-Tetradecadien-1-yl Acetate	31654-77-0	Mating disruption for control of the Indian meal moth, Mediterranean flour moth, Raisin moth, and Tobacco moth	Dispenser	56336-54
CheckMate® VMB XL	Suterra, LLC CP Pheromones	Lavandulyl senecioate	23960-07-8	Mating disruption for control of the vine mealybug	Dispenser	56336-57
CheckMate® LBAM Dispenser	Suterra, LLC CP Pheromones	(E)-11-Tetradecen-1-yl acetate; (E,E)-9, 11-Tetradecadien-1-yl acetate	33189-72-9; N/A	Mating disruption for control of the light brown apple moth	Dispenser	56336-58

Product Name	Manufacturer	Chemical Name of Pheromone(s) (Active Ingredients)	CAS No.	Intended Use and Target Organism	Delivery/Application Method	EPA Reg. No.
Checkmate® CM Primo	Suterra, LLC CP Pheromones	E,E-8, 10-Dodecadien-I-ol	33956-49-9	Mating disruption for control of the codling moth and hickory shuckworm	Dispenser	56336-61
Lures						
German cockroach pheromone lure	Woodstream Corp.	German cockroach pheromone	N/A	Improve [enhance] the attractiveness [effectiveness] of insect glue-boards, insect monitoring devices and insecticidal baits for German cockroaches	Lure (sticky, to be added to glue boards)	47629-8
Oriental beetle MD	Agbio Development Inc.	Z-7-Tetradecen-2-one	146955-45-5	Reduce populations of oriental beetle (in combination with trap)	Lure	68253-1
BioLure	Suterra, LLC	N/A	N/A	Variety	Trap	N/A
Scentry® Methyl Eugenol Cone	Scentry Biologicals, Inc.	Methyl Eugenol	93-15-2	Semiochemical insect attractant for control of the oriental fruit fly	Lure	36638-41
Scentry® Cue-Lure Plug	Scentry Biologicals, Inc.	4-[p-Acetoxyphenyl]-2-butanone	3572-06-3	Semiochemical insect attractant for control of the melon fly	Lure	36638-42
Fibers						
NoMate® PBW Fiber	Scentry Biologicals, Inc.	(Z,E)-7,11-Hexadecadien-1-yl acetate; (Z,Z)-7,11-Hexadecadien-1-yl acetate	53042-79-8; 52207-99-5	Mating disruption for control of the pink bollworm	Fibers (placed in foliage)	36638-23
NoMate® CM Fiber	Scentry Biologicals, Inc.	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth	Fibers (placed in foliage)	36638-36
Microencapsulated pheromones (MECs)						
NoMate® PBW MEC	Scentry Biologicals, Inc.	(Z,E)-7,11-Hexadecadien-1-yl acetate ; (Z,Z)-7,11-Hexadecadien-1-yl acetate	53042-79-8; 52207-99-5	Mating disruption for control of the pink bollworm	Spray (ground)	36638-25
NoMate® TPW MEC	Scentry Biologicals, Inc.	(Z)-4-Tridecen-1-yl acetate ; (E)-4-Tridecen-l-yl acetate	65954-19-0; 72269-48-8	Mating disruption for control of the tomato pinworm	Spray (ground)	36638-28
Mists/Sprays						
Isomate® -CM Mist	Pacific Biocontrol Corp.	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth	Spray (aerial or ground)	53575-42
CheckMate® LBAM-F	Suterra, LLC	(E)-11-Tetradecen-1-yl acetate; (E,E)-9,11-Tetradecadien-1-yl acetate	33189-72-9; N/A	Mating disruption for control of the light brown apple moth	Spray (aerial or ground)	56336-59
CheckMate® OLR-F	Suterra, LLC	(Z)-11-Tetradecenyl acetate; 11-Tetradecen-1-ol, acetate, (E)-	20711-10-8; 33189-72-9	Mating disruption for control of the omnivorous leafroller	Spray (aerial or ground)	56336-25
CheckMate® DBM-F	Suterra, LLC	(Z)-11-Hexadecenal; (Z)-11-Hexadecenyl acetate	53939-28-9; 34010-21-4	Mating disruption for control of the diamondback moth	Spray (aerial or ground)	56336-35
CheckMate® CM-F	Suterra, LLC	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth	Spray (aerial or ground)	56336-37

Product Name	Manufacturer	Chemical Name of Pheromone(s) (Active Ingredients)	CAS No.	Intended Use and Target Organism	Delivery/Application Method	EPA Reg. No.
CheckMate® NOW-F	Suterra, LLC	Navel orangeworm pheromone	71317-73-2	Mating disruption for control of the navel orangeworm	Spray (aerial or ground)	56336-38
CheckMate® APM-F	Suterra, LLC	(Z)-11-Hexadecenal	53939-28-9	Mating disruption for control of the artichoke plume moth	Spray (aerial or ground)	56336-39
CheckMate® WPCM-F	Suterra, LLC	(3E, 13Z)-Octadecadien-1-ol; (Z,Z)-3, 13-Octadecadien-1-ol	66410-24-0; 66410-28-4	Mating disruption for control of the western poplar chewing moth	Spray (aerial or ground)	56336-40
CheckMate® PTB-F	Suterra, LLC	(E)-5-Decen-1-ol; 5-Decen-1-ol, acetate, (E)-	56578-18-8; 38421-90-8	Mating disruption for control of the peachtree borer	Spray (aerial or ground)	56336-41
CheckMate® OFM-FXL	Suterra, LLC	(Z)-8-Dodecen-l-yl Acetate; (E)-8-Dodecen-I-yl Acetate; (Z)-8-Dodecen-I-01	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth, macadamia nut borer, and koa seedowrm	Spray (aerial or ground)	56336-42
CheckMate® BAW-F	Suterra, LLC	(Z,E)-9,12-Tetradecadienyl acetate ; (Z)-11-Hexadecenyl acetate	30507-70-1; 34010-21-4	Mating disruption for control of the beet armyworm moth	Spray (aerial or ground)	56336-43
CheckMate® TPW	Suterra, LLC CP Pheromones	(E)-4-Tridecen-1-yl acetate; (Z)-4-Tridecen-1-yl acetate; water	77269-48-8; 65954-19-0; 7732-18-5	Mating disruption for control of the tomato pinworm.	Spray (aerial or ground)	56336-21
CheckMate® PBW	Suterra, LLC CP Pheromones	(Z,E)-7,11-Hexadecadien-1-yl acetate ; (Z,Z)-7,11-Hexadecadien-1-yl acetate	53042-79-8; 52207-99-5	Mating disruption for control of the pink bollworm	Spray (aerial or ground)	56336-1
Consep Spr2m Oriental Fruit Moth Sprayable Bead Pheromone	Suterra, LLC CP Pheromones	(Z)-8-Dodecen-1-yl acetate; (E)-8-Dodecen-1-yl acetate; Z-8-DDOL	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth	Spray (aerial or ground)	56336-24
Consep Spr3 Codling Moth Pheromone Sprayable	Suterra, LLC CP Pheromones	E,E-8,10-dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth	Spray (aerial or ground)	56336-11
Consep Spr4m Peach Twig Borer Sprayable Bead Pheromone	Suterra, LLC CP Pheromones	(E)-5-Decen-1-ol; 5-Decen-1-ol, acetate, (E)-	56578-18-8; 38421-90-8	Mating disruption for control of the peach twig borer	Spray (aerial or ground)	56336-23
Consep Spr5m PBW Sprayable Bead Pheromone	Suterra, LLC CP Pheromones	(Z,E)-7,11-Hexadecadien-1-yl acetate; (Z,Z)-7,11-Hexadecadien-1-yl acetate	53042-79-8; 52207-99-5	Mating disruption for control of the pink bollworm	Spray (aerial or ground)	56336-19
Flakes						
HERCON disrupt bio-flake LBAM	Hercon	9,11-Tetradecadien-1-ol, acetate, (9E, 11E)-; 11-Tetradecen-1-ol, acetate, (E)-	54664-98-1; 33189-72-9	Mating disruption for control of the light brown apple moth	Polymer flakes for a passive release of semiochemicals; applied using specialized air or ground equipment	8730-73

Product Name	Manufacturer	Chemical Name of Pheromone(s) (Active Ingredients)	CAS No.	Intended Use and Target Organism	Delivery/Application Method	EPA Reg. No.
HERCON disrupt bio-flake GM	Hercon	cis-7,8-Epoxy-2-methyloctadecane	29804-22-6	Mating disruption for control of the gypsy moth	Polymer flakes for a passive release of semiochemicals; applied using specialized air or ground equipment	8730-75
HERCON disrupt bio-flake VBN	Hercon	Verbenone	1196-01-6	Mating disruption for control of the bark beetle	Polymer flakes for a passive release of semiochemicals; applied using specialized air or ground equipment	8730-77
HERCON disrupt bio-flake CM	Hercon	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth	Polymer flakes for a passive release of semiochemicals; applied using specialized air or ground equipment	8730-74
HERCON disrupt micro-flake CM	Hercon	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of the codling moth	Polymer flakes for a passive release of semiochemicals; applied using specialized air or ground equipment	8730-65
HERCON disrupt micro-flake VBN	Hercon	Verbenone	1196-01-6	Mating disruption for control of the bark beetle	Polymer flakes for a passive release of semiochemicals; applied using specialized air or ground equipment	8730-68
HERCON disrupt micro-flake MCH	Hercon	3-Methyl-2-cyclohexen-1-one	1193-18-6	Mating disruption for control of certain bark beetle species including Douglas-fir beetle, Engelmann spruce, and other spruce tree species	Polymer flakes for a passive release of semiochemicals; applied using specialized air or ground equipment	8730-72

Source: NPIRS, 2012

Appendix B. Commercially Available Pheromone Products that are Listed with OMRI

Product Name:	Manufacturer:	Chemical Name of Pheromone (Active Ingredients)	CAS No.	Intended Use and Target Organism	Application Method:	EPA Reg. No.
Biomite™	Natural Plant Protection	Farnesol; Nerolidol; Cephrol; Geraniol	4602-84-0; 7212-44-4; 106-22-9; 106-24-1	Controls mites, *Eotetranychus* spp., *Tetranychus* spp. and *Panonychus* spp, including two-spotted mites, pacific mite, willamette mite, citrus rust mite, broad mite and the European red mite; novel mode of action inhibits the development of resistance	Spray	70057-1
Checkmate® OFM-SL+	Suterra, LLC CP Pheromones	(Z)-8-Dodecen-1-yl acetate; (E)-8-Dodecen-1-yl acetate; (Z)-8-Dodecen-1-ol	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth, macadamia nut borer, and koa seedworm	Dispenser	56996-50
CheckMate® OFM	Suterra, LLC CP Pheromones	(Z)-8-Dodecen-1-yl acetate; (E)-8-Dodecen-1-yl acetate; (Z)-8-Dodecen-1-ol	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of oriental fruit moth, macadamia nut borer, and koa seedworm.	Dispenser	56336-3
Isomate® - C Plus	Pacific Biocontrol Corp.	(E, E)-8, 10-Dodecadien-1-ol; 1-Dodecanol; 1-Tetradecanol	33956-49-9; 112-53-8; 112-72-1	Mating disruption for control of the codling moth and hickory shuckworm	Dispenser	53575-6
Isomate® - C TT	Pacific Biocontrol Corp.	(E, E)-8, 10-Dodecadien-1-ol; Dodecanol; Tetradecanol	33956-49-9; 112-53-8; 112-72-1	Mating disruption for control of the codling moth and hickory shuckworm	Dispenser	53575-25
Isomate® - CM FLEX	Pacific Biocontrol Corp.	Dodecyl alcohol; Tetradecyl alcohol; (E,E)-8,10-Dodecadien-1-ol	112-53-8; 112-72-1; 33956-49-9	Mating disruption for control of the codling moth and hickory shuckworm	Dispenser	53575-32
Isomate® - CM RING	Pacific Biocontrol Corp.	Dodecyl alcohol; Tetradecyl alcohol; (E,E)-8,10-Dodecadien-1-ol	112-53-8; 112-72-1; 33956-49-9	Mating disruption for control of the codling moth and hickory shuckworm	Dispenser	53575-35
Isomate® - CM/OFM TT	Pacific Biocontrol Corp.	(E, E)-8, 10-Dodecadien-1-ol; Dodecanol; Tetradecanol; Z-8-Dodecen-1-yl acetate; E-8-Dodecen-1-yl acetate; Z-8-Dodecen-1-ol	33956-49-9; 112-53-8; 112-72-1; 28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the codling moth, oriental fruit moth, macadamia nut borer, koa seedworm, and lesser appleworm	Dispenser	53575-30
Isomate® - EGVM	Pacific Biocontrol Corp.	(E,Z)-7,9-Dodecadien-1-yl Acetate	55774-32-8	Mating disruption for control of the European grapevine moth.	Dispenser	53575-36
Isomate® - M Rosso	Pacific Biocontrol Corp.	Z-8-Dodecen-1-yl acetate; E-8-Dodecen-1-yl acetate; Z-8-Dodecen-1-ol	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth, macadamia nut borer, and koa seedworm	Dispenser	53575-26
Isomate® - OFM TT	Pacific Biocontrol Corp.	Z-8-Dodecen-1-yl acetate; E-8-Dodecen-1-yl acetate; Z-8-Dodecen-1-ol	28079-04-1; 38363-29-0; 40642-40-8	Mating disruption for control of the oriental fruit moth, macadamia nut borer, and koa seedworm	Dispenser	53575-29
Isomate® - OFM/PTB TT	Pacific Biocontrol Corp.	(Z)-8-Dodecen-1-yl acetate; (E)-5-Decenyl acetate; (E)-8-Dodecen-1-yl acetate; (E)-5-Decen-1-ol; (Z)-8-Dodecen-1-ol	28079-04-1; 38421-90-8; 38363-29-0; 56578-18-8; 40642-40-8	Mating disruption for control of the peach twig borer and oriental fruit moth	Dispenser	53575-37

Product Name:	Manufacturer:	Chemical Name of Pheromone (Active Ingredients)	CAS No.	Intended Use and Target Organism	Application Method:	EPA Reg. No.
Isomate® - OMLR	Pacific Biocontrol Corp.	E-11-Tetradecen-1-yl acetate; Z-11-Tetradecen-1-yl acetate	33189-72-9; 20711-10-8	Mating disruption for control of the omnivorous leafroller	Dispenser	53575-28
Isomate® - PTB TT	Pacific Biocontrol Corp.	(E)-5-Decenyl acetate; (E)-5-Decen-1-ol	38421-90-8; 56578-18-8	Mating disruption for control of peach twig borer.	Dispenser	53575-38
PB - Rope L	Pacific Biocontrol Corp.	(Z, Z)-7, 11-Hexadecadien-1-yl acetate; (Z, E)-7, 11-Hexadecadien-1-yl acetate	52207-99-5; 51607-94-4	Mating disruption for control of the pink bollworm	Dispenser	53575-15
NoMate® CM-O Spiral	Scentry Biologicals, Inc.	(E,E)-8,10-Dodecadien-1-ol	33956-49-9	Mating disruption for control of codling moth.	Dispenser	36638-30

Sources: OMRI, 2012; NPIRS, 2012