"Though they spray for mosquitoes, bees find a way to visit."
Photo by Bev Veals, Kure Beach NC.

Mosquito Control and Pollinator Health

Protecting pollinators in the age of Zika and other emerging mosquito diseases

by Nichelle Harriott

In 2015, a beekeeper in Palo Alto, California, Randolph Tsien, made local headlines after he reported the loss of hundreds of honey bees from his backyard hives following the local fogging for mosquitoes carrying West Nile virus. In addition to losing his honey bees, Mr. Tsien was concerned about the contamination of his honey, which he once labeled 'organic.' Like Mr. Tsien, every year beekeepers and concerned citizens worry about the impact of mosquito control programs on honey bees and other pollinators. During the summer, mosquitoes become more active and the potential public health risks associated with them begin to make national headlines.

While mosquito-borne transmission of Zika virus has not been reported in the U.S., the virus has been found in travelers to the U.S. from countries where infected mosquitoes have been reported. (Centers for Disease Control (CDC), 2016) In 2015, 48 states and the District of Columbia reported West Nile virus infections in people, birds, or mosquitoes, with most people reporting no symptoms; 2,060 cases were reported to the CDC. Dengue is rarely reported in the continental U.S. and no mosquito-borne cases of chikungunya have been reported in the U.S. As mosquito abatement districts across the country gear up during the summer, it is prudent to keep in mind that while mosquito management is a necessary public health service, common methods of control –aerial and ground spraying of pesticides– not only have questionable efficacy, but can also harm non-target organisms like pollinators, whose populations are already suffering elevated losses.

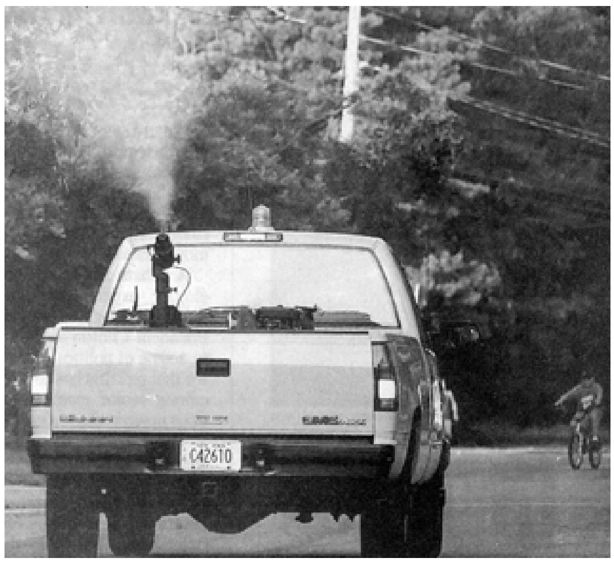
In this piece, we explore how commonly used mosquito control pesticides and their application can potentially harm bees, butterflies, and other beneficial insects, ultimately affecting overall biodiversity. While we do not underestimate the threat from new and current mosquito-borne diseases, an ideal mosquito management strategy adopts an integrated approach that emphasizes education, aggressive removal of breeding sites (such as standing water), larval control, monitoring, and surveillance. Alternative strategies, including introducing mosquito-eating fish, encouraging predators, such as bats, birds, dragonflies, and frogs, and using least-toxic larvicides, like *Bacillus thuringiensis* (Bt), can be applied successfully without endangering pollinators and other organisms.

A note about wild native bees: While this article cites data regarding honey bees, wild native bees are equally, or even more, at risk from mosquito pesticides. Studies note that certain wild bee species are more susceptible to pesticide exposure than honey bees, due to differences in biology and habitat. One author observed that the trend in susceptibility to pesticides is directly correlated to the surface/volume ratios –which influence contact exposures of wild bee species, with the susceptibility sequence (lowest to highest) as follows: *alfalfa leaf cutting bee –> alkali bee –> honey bee –> bumble bees*.[1]

People can protect themselves from mosquitoes by using least-toxic repellents like oil of lemon eucalyptus, wearing light long-sleeve clothing when outdoors, and avoiding outdoors when mosquitoes are most active.

Widespread spraying: more risk than benefit

Pollinators are facing unprecedented declines and pesticides have been identified as one of the main contributing factors in their decline. A recent government survey put honey bee hive losses between April 2015 and April 2016 at 44 percent, the second highest on record.[2] Insecticides, like neonicotinoids, have been especially singled out as a major contributor because of their widespread use in agriculture –foliar sprays and seed coatings– and in home gardens, their elevated toxicity to honey bees, and prolonged exposure as a result of their persistence and systemic contamination of pollen and nectar, and other parts of the plant. Spray applications and the planting of seeds coated with these pesticides have resulted in large bee deaths in urban and agricultural landscapes across North America and Europe.[3] And while neonicotinoids have attracted the most scrutiny, other classes of pesticides are also highly toxic to bees. These include pyrethroid and organophosphate insecticides, which are widely used in public health mosquito control programs across the U.S.



Mosquito abatement programs can vary across states, but most involve widespread aerial and ground spraying of insecticides across urban and rural areas to control disease-carrying mosquitoes. Common insecticides used as part of these programs include permethrin, malathion, naled, phenothrin (sumithrin), pyrethrin, and resmethrin (which was withdrawn in 2015, but existing stocks may still be used).

The application of these pesticides puts bees, birds and other pollinators in harm's way. Impacts on these non-target organisms may be exacerbated by the increased use frequency of mosquito control insecticides within short time durations, which may occur during periods of high mosquito pressure.[4] When it comes to regulating mosquito pesticides used to control mosquito-borne diseases, oftentimes additional mitigation measures or use restrictions for these pesticides are typically waived for public health mosquito control uses, putting non-target organisms at risk, contaminating water bodies, and increasing hazards to humans.

"To fully protect honey bees and native pollinators from mosquito control pesticides, the pesticide should only be applied when it is dark, the sun has set and the street lights are lit. Dark is dark, not twilight, not sunset: dark."
–Pollinator Stewardship Council

"The mitigation measures proposed for when bees are present under contract pollination would not apply to applications made in support of public health, such as use for wide area mosquito control. EPA recognizes that a wide area mosquito control application can impact large numbers of bees if the application co-occurs in areas with pollinator-attractive plants; however, such applications utilizing products classified as acutely toxic to bees are used to protect public health through mosquito abatement."
–EPA 2015

Large-scale mosquito control applications are made with ultra-low volume (ULV) sprays that dispense very fine droplets of the pesticide product into the air, killing mosquitoes and other non-target insects that come into contact with the fine mist. Because ULV sprays target adult flying mosquitoes, they are only a temporary control measure. The sprayed pesticides do not affect mosquito larvae left behind to propagate another generation of adult mosquitoes, ensuring the need for subsequent spraying. According to one study, flying insect abundance decreases after ULV application of insecticides, while larval mosquitoes remain.[5] Additionally, because the ULV spray can only kill mosquitoes that the fine particles come into contact with, the number of which may be limited (one study notes that less than 0.0001% of the insecticide reaches the target mosquitoes),[6] this method is not an effective long-term strategy to effectively control mosquito populations. The efficacy of ULV spraying also depends on time of day applied, and weather factors, such as wind velocity and direction, temperature, and atmospheric stability and turbulence.[7] In addition, some species of mosquitoes, like the *Aedes* species (e.g. *Aedes aegypti*),[8] are more active during the daytime and some even prefer being indoors, all of which can impact the effectiveness of ULV spraying.

Typically, mosquito abatement programs spray at or near dusk, or twilight, when most adult mosquitoes are active. There is a common misconception that conducting ULV mosquito applications in the late afternoon is ideal, assuming bees are not active during this time. But according to the Pollinator Stewardship Council (PSC), a national beekeeping organization, this is false. PSC notes that honey bees and native pollinators will forage blooming plants until the sun sets, and can be active during dusk, right up till nightfall.[9] Additionally, warm nighttime temperatures and high humidity may induce bee aggregation at the hive entrances, even though they are not actively foraging.

What can kill mosquitoes *CAN* kill pollinators

The U.S. Environmental Protection Agency (EPA) has identified 76 pesticide chemicals that are highly acutely toxic to honey bees.[10] These were singled out because they have an acute contact toxicity value of less than 11 micrograms per bee (LD50<11 micrograms/bee) and can be applied in ways that can expose bees. Of these, several are used to control mosquitoes, including malathion, naled, permethrin and phenothrin, which are the most commonly used for ultra-low volume aerial and ground spraying (see *Table 1*, p13).

A. Organophosphates: Malathion, Naled, and others

The organophosphate malathion is widely used in many mosquito control districts across the country and has been used since the 1960s. It is an adulticide, meaning it targets only the adult stage of the mosquito, and not the juvenile/larval stage. Applied by both ground and aerial ULV spraying, malathion spray drift can travel and impact a wide area, exposing non-target organisms and humans alike. These applications have resulted in the death of many bees and impaired bee colonies due to daytime application of malathion.[11] Studies have reported that colonies exposed to ULV malathion weighed significantly less for up to 28 days when compared to control colonies, indicating colony decline.[12]

Malathion. Malathion is highly toxic to honey bees (LD50 of 0.71 micrograms/bee). Residues on plants and other surfaces indirectly expose bees to malathion, which is also systemically absorbed by plants, translocating throughout the plant and into pollen and nectar, further exposing foraging bees.[13] Bees carrying contaminated pollen back to the hive unwittingly expose the entire colony to malathion residues. Honey bees, pollen, wax and honey have all been found to be contaminated with malathion residues, according to Johnson et al. (2010).[14] Exposures to worker bees have been found to decrease their longevity.[15]

Aquatic organisms, including fish, invertebrates, and amphibians, are also severely affected by malathion, as the insecticide is highly toxic to these organisms. According to EPA's registration documents for malathion, there are several toxicity studies with aquatic insect larvae that show malathion is highly to very highly toxic to non-target insects with aquatic early life stages.[16] This, coupled with the fact that it is very soluble in water, has a half-life of approximately one week, and is more stable in acidic aquatic conditions,[17] makes malathion a threat to non-target species. As a result of malathion's toxicity to non-target organisms, precautionary statements are required on malathion product labels in an attempt to limit exposure to honey bees and other beneficial insects during applications of malathion.[18]

Naled. Like malathion, naled, commonly known by its trade name Dibrom, has been used for mosquito control for several decades. Elevated mortality rates

As organophosphate insecticides, both malathion and naled can affect the human nervous system causing nausea, confusion and dizziness, as well as respiratory distress. Long-term neurological effects have also been documented.

among honey bees have been documented after nighttime aerial ULV applications of naled.[19] Additionally, average yield of honey per hive is significantly lower in exposed hives.[20] Naled is highly toxic to honey bees (LD50 0.48 micrograms/bee)[21] and some have observed that naled killed bees at 30 and 60 meters from the path of ground ULV applications.[22] Consequently, ground application and the subsequent deposition on surfaces show a positive correlation with bee mortality.[23] Adult bees are more sensitive to naled than younger bees,[24] though studies show a significant decrease in residual toxicity from 3 to 24 hours post-treatment.[25] EPA registration documents note that naled is moderately to very

Following the Label

Label directions are often difficult to follow and not adhered to in the real-world. Many beekeepers can attest to this and have repeatedly communicated this to EPA enforcement and registration officials. The images below are pieces taken from a 22 page booklet attached to the product Ortho® MAX® Malathion Insect Spray Concentrate (which is considered the product label). The environmental hazards section, which gives specific instructions for protecting bees, appear on the back cover and on page 10 (circled in red). It states: "Do not apply this product or allow it to drift to blooming crops or weeds while bees are actively visiting the treatment area."

NUISANCE INSECTS – Outdoors Only

TO KILL THESE INSECTS	Clover Mites, Ants (except Fire, Pharoah, Carpenter and Harvester Ants), Crickets, Earwigs, Roaches, Spiders, and Adult Mosquitoes.	
IN THESE AREAS	Exterior House Foundation; Patios and Garbage Cans; under Porches and Shrubbery; Along Fences; Firewood Piles; and Ornamental Vegetation	
	INSECT	**AMOUNT**
USE THIS AMOUNT	**Clover Mites**	2 tsp per gallon of water. Ortho® Dial 'N Spray® setting is 2 tsp.
	Ants, Crickets, Earwigs, Roaches & Spiders	8 Tbs (4 fl oz) per gallon of water. Ortho® Dial 'N Spray® setting is 4 oz.
	Adult Mosquito Control	9 Tbs per gallon of water. (use tank sprayer only)
HOW TO APPLY	•Use an Ortho® Dial 'N Spray® or tank sprayer. •Apply as a coarse spray to the lower outside foundation of house, patios and garbage cans; under porches and shrubbery; along fences; to firewood piles; and ornamental vegetation where mosquitoes may rest. •**Specific directions for Clover Mites:** Spray a 2-ft wide strip along side of house. •**DO NOT USE INSIDE THE HOME. DO NOT USE ON ANIMALS.**	
WHEN TO	Apply as necessary to control listed insects; waiting at least	

ENVIRONMENTAL HAZARDS

This pesticide is toxic to aquatic organisms, including fish and invertebrates. To protect the environment, do not allow pesticide to enter or run off into storm drains, drainage ditches, gutters or surface waters. Applying this product in calm weather when rain is not predicted for the next 24 hours will help ensure that wind or rain does not blow or wash pesticide off the treatment area. Rinsing application equipment over the treated area will help avoid run off to water bodies or drainage systems. Drift and run off may be hazardous to aquatic organisms in areas near the application site. This product is highly toxic to bees exposed to direct treatment on blooming crops or weeds. Do not apply this product or allow it to drift to blooming crops or weeds while bees are actively visiting the treatment area.

PHYSICAL OR CHEMICAL HAZARDS: Combustible. Do not use or store near heat or open flame.

NOTICE: To the extent consistent with applicable law, buyer assumes all risks of use, storage, or handling of this product not in accordance with directions.

The ORTHO® Guarantee: If for any reason you, the consumer, are not satisfied with this product, mail us your original proof of purchase to obtain a full refund of your purchase price.

DIRECTIONS FOR USE

It is a violation of Federal law to use this product in a manner inconsistent with its labeling.

Precautions and Restrictions:

DO NOT APPLY THIS PRODUCT IN A WAY THAT WILL CONTACT ANY PERSON OR PET, EITHER DIRECTLY OR THROUGH DRIFT. KEEP PEOPLE AND PETS OUT OF THE AREA DURING APPLICATION.

DO NOT ALLOW PEOPLE OR PETS TO ENTER TREATED AREA UNTIL SPRAYS HAVE DRIED.

Do not use food utensils such as teaspoons and tablespoons for food purposes after use with pesticides.

tsp = teaspoon   Tbs = Tablespoon
3 teaspoons (tsp) = 1 Tablespoon (Tbs) = ½ fl oz

When using Ortho® Dial 'N Spray®

1. Set dial to the setting indicated in the use directions for your specific application.
2. Pour product into sprayer to fill jar one-quarter to one-half full.
3. After spraying, unused product must be poured back into its original container.

When using a tank sprayer

1. Blend appropriate amount of Ortho® MAX® Malathion Insect Spray Concentrate with appropriate amount of water following the dilution instructions for each site-pest combination listed below.
2. Operate sprayer by following the manufacturer's instructions. Spray as directed below.

Applying a pesticide to mosquito breeding ground site in waterbody in Monmouth County, NJ. Photo courtesy NJTV News.

highly toxic to freshwater fish on an acute basis, and very highly toxic to freshwater aquatic invertebrates.

Dichlorvos. Naled degrades into dichlorvos, which is also registered as a pesticide and used in mosquito control products. Dichlorvos is also highly toxic to bees (LD50 0.495 micrograms/bee) and EPA notes that exposure "may lead to mortality to this and other insect pollinators." Similarly, EPA states, "Listed plant species dependent upon insect pollination may be indirectly affected by the loss of all or part of such insect populations. Additionally, the potential risk to bird species from dichlorvos use could also affect bird-pollinated plant species."[26]

Chlorpyrifos. Chlorpyrifos, a controversial organophosphate known for its neurotoxicity and impacts on children's learning and development, is also highly toxic to honey bees (LD50 is 0.36 micgrogram/bee).[27] Honey bees experience a learning and memory deficit after ingesting small doses of the chemical, potentially threatening their success and survival, according to Urlacher et al. (2016).[28] Although most residential uses were cancelled in 2001, it can still be used for public health mosquito control, despite efforts to have the chemical completely banned, and is frequently been detected in honey bees. According to a study conducted in 2015 by the U.S. Geological Survey (USGS), 17% of bees tested positive for chlorpyrifos residues.[29]

B. Pyrethroids: Permethrin, Phenothrin, Resmethrin and others

When it comes to honey bees, synthetic pyrethroids, introduced in the 1960s, are generally highly toxic. In spite of this, mosquito control officials commonly say that pyrethroids pose minimal risk to bees due to their low application rates in the field and claimed repellent properties.[30] However, real-world and laboratory evidence dispute this. Pyrethroids are frequently associated with bee kills and colony collapse disorder (CCD)-like symptoms, characterized by bees' disappearance from their hives.[31] One study reports that after exposure to sublethal levels of permethrin (0.009 micrograms/bee), worker bees failed to return to the hive at the end of day, while only 43% of these bees were eventually able to return to the hive because of disorientation due to treatment.[32] Pyrethroids have also been found to significantly reduce bee fecundity, decrease the rate at which bees develop to adulthood, and increase their immature periods.[33] A 2015 study finds that exposure to pyrethroids reduces bee movement and social interaction.[34] This study also found that pyrethroid-exposed bees travel 30-71% less than unexposed bees, and those exposed to both the pyrethroids esfenvalerate and permethrin decreased social interaction time by 43% and 67%, respectively.

Salvato (2001), who examined the toxicity of naled, malathion, and permethrin to five species of butterflies, including larval and adult stages, found that naled and permethrin were the most toxic to all life stages.[35] Resmethrin adversely affects butterfly larvae and adults directly exposed to resmethrin ULV spray.[36] In a similar study by Hoang et al. (2011), which looked at the impact of mosquito control pesticides on non-target organisms, several butterfly species were found to be more sensitive to these insecticides than honey bees.[37]

High levels of pyrethroids have been detected in pollen collected by honey bees. One study by Penn State and USDA researchers finds that pyrethroids are quantitatively the most prevalent of pollen residues, with up to 10 different pyrethroid compounds per sample.[38] A recent study by Long and Krupke (2016) notes that

A note about insecticide resistance in mosquitoes:

The more insecticides are relied upon to control mosquito populations, the quicker mosquitoes develop resistance to the insecticides. According to Liu (2015), a large number of studies show that multiple, complex resistance mechanisms, like increased metabolic detoxification of insecticides, is likely responsible for mosquito resistance.[39] In general, genetic mutations result in mosquito resistance to pyrethroids, organophosphates, and carbamates.[40] The World Health Organization (WHO) has documented mosquito resistance to pyrethroid, organochlorine, organophosphate, and carbamate insecticide classes across the globe.[41] To combat mosquito resistance, the dependency on chemical control must be addressed and lead to more sustainable methods, which include habitat modification, improved sanitation, and use of natural controls.

Table 1: Pesticides Used for Mosquito Control

Pesticides Registered by EPA for Mosquitoes as a Target Pest[i]	Used in Vector Control Programs[ii]	Toxic to Honey Bees[iii]	Toxic to Other Non-Target Organisms
Larvicides: Biological Controls			
Bacillus thuringiensis israelensis			Not documented.
Bacillus thuringiensis sphaericus			Not documented.
Spinosad		✓	✓ Very highly toxic to oysters.
Larvicides: Synthetic			
Diflubenzuron			✓ Very highly toxic to freshwater aquatic invertebrates.
Growth Inhibitors			
Methoprene		✓[iv]	✓ Toxic to some fish, highly toxic to freshwater invertebrates and amphibians.
Pyriproxyfen			✓ Toxic to aquatic invertebrates and crustaceans.
Adulticides			
Acetamiprid		✓	Not documented.
Bifenthrin		✓	✓ Toxic to fish, aquatic invertebrates.
Carbaryl		✓	✓ Highly toxic to fish and other aquatic organisms, including amphibians.
Chlorpyrifos	✓	✓	✓ Very highly toxic to freshwater fish, aquatic invertebrates and estuarine and marine organisms.
Cypermethrin		✓	✓ Toxic to fish.
Deltamethrin	✓	✓	✓ Toxic to fish.
Dichlorvos		✓	✓ Highly toxic to birds and aquatic organisms.
Dinotefuran		✓	✓ Highly toxic to estuarine and marine invertebrates.
d-Phenothrin (Sumithrin)	✓	✓	✓ Toxic to fish.
D-trans-allethrin		✓	✓ Toxic to fish.
Esfenvalerate	✓	✓	✓ Toxic to fish and aquatic organisms.
Etofenprox	✓	✓	✓ Toxic to fish.
Imidacloprid		✓	✓ Toxic to aquatic organisms, birds.
Lambda-cyhalothrin		✓	✓ Toxic to fish.
Malathion	✓	✓	✓ Toxic to aquatic organisms, including fish and invertebrates.
Naled	✓	✓	✓ Toxic to aquatic invertebrates.
Permethrin[v]	✓	✓	✓ Toxic to fish.
Prallethrin	✓	✓	✓ Toxic to fish.
Pyrethrins	✓	✓	✓ Toxic to fish.
Resmethrin[vi]	✓	✓	✓ Toxic to fish.
Tau-fluvalinate			✓ Toxic to fish.
Tetramethrin		✓	✓ Toxic to fish.
Zeta-cypermethrin		✓	✓ Toxic to fish.
Other			
MGK-264 (synergist)			✓ Toxic to fish and aquatic organisms.
Mineral oils (surface film)			Not documented.
Piperonyl Butoxide (synergist)	✓		✓ Toxic to fish and aquatic organisms.

[i] These include chemicals available over the counter or used by commercial applicators.
[ii] These products can be used for community Ultra Low Volume (ULV) spray programs for vector control, both as aerial and ground spraying.
[iii] EPA's list of registered active ingredients that meet the acute toxicity criteria. Taken from *EPA's Proposal to Mitigate Exposure to Bees from Acutely Toxic Pesticide Product*. Docket Number: EPA-HQ-OPP-2014-0818.
[iv] Honey bee larvae more sensitive.
[v] Permethrin is also used for treated clothing.
[vi] Resmethrin was voluntarily cancelled in Dec 2015, but existing stocks may still be used until they are exhausted.

two synthetic pyrethroids in particular, phenothrin and prallethrin, used primarily to manage mosquitoes, stood out as posing exceptionally high risks to honey bees throughout the sampling period and across all sites, with risk values consistently greater than 5%. Permethrin can persist in sediment, soil, and plant tissue for weeks to months and has a half-life on plants of about 35 days.[42] According to studies reviewed by EPA, applications of permethrin formulations are likely to reduce the numbers and possibly eliminate populations of beneficial insects.[43] Further, pyrethroids in general are highly toxic to both freshwater and estuarine aquatic organisms.

C. Insect growth regulators, larvicides and surface films

Larvicides, many of which are insect growth regulators (IGRs), and surface films are also used as part of mosquito control programs to target juvenile mosquitoes. IGRs disrupt the juvenile life cycles of insects. Larvicides are applied to the breeding habitat (pooled surface waters, e.g. lakes, marshes, shallow ponds, etc.) to kill mosquito larvae before they can mature into adult mosquitoes. Commonly used larvicides include the synthetic methoprene, and biologicals spinosad, *Bacillus thuringiensis israelensis* and *Bacillus thuringiensis sphaericus*. Their use does not appear to impact honey bees, even though the IGR methoprene is toxic to certain aquatic organisms and invertebrates at the larval stage. Studies have observed physical malformations in adult bees exposed during the larval stage, and bee larvae are sensitive to the effects of methoprene and other IGRs.[44] Another larvicide,

Beekeeping During Mosquito Spraying

Mosquito spray programs differ by state in terms of pesticides used, application methods, and notification. It is important for beekeepers to be familiar with the mosquito spray operations in their locality. Contrary to what is said by mosquito officials, mosquito pesticides can linger in the environment for long periods of time, exposing bees long after spraying is completed. To protect managed bees from direct spraying, beekeepers can:

Stay Informed. Keep up-to-date on mosquito spraying. Information may be listed in local newspapers, or on local radio and television programming. Contact your local health department or mosquito control program and let them know you are concerned about the dangers of the mosquito control spray program. Some cities offer beekeepers the opportunity to “opt-out” of mosquito spray applications.

Cover Hives. While not entirely protective, entire hives can be covered to prevent pesticide drift into and onto the hive. It is recommended to use wet burlap or other breathable material, and it is important to cover the entrance to prevent foragers from going out during spraying.

Move Hives. Moving hives to a location where pesticides are not being applied is another option. If viable, move them at least two miles away to prevent bees from attempting to return to their previous location. However, moving bees may reduce exposure risk during spraying, but as discussed, residues can linger in the environment and can still potentially pose risks when hives are returned.

While there are some steps beekeepers can take to reduce risks to their hives, wild, native bees do not have such protections and remain at risk. Mosquito spraying, even when conducted late in the day, can and do threaten native bees long after spraying is completed.

Photo by Cohee courtesy WikiMedia Commons.

temephos, an organophosphate, was once commonly used, but its registration was cancelled in 2011 with all remaining stocks to be discontinued by December 2016.[45]

Surface films or oils (monomolecular films) are also added to mosquito breeding habitats to disperse as an ultra-thin layer (one molecule in thickness) on the surface of the water. Their mode of action against mosquito larvae and pupae is physical rather than chemical. The film interrupts the critical air/water interface in the mosquito's larval and pupal development cycle, preventing suspension of the larvae and pupae at the water surface, and subsequently suffocating/drowning them.[46] Unfortunately, certain other aquatic insects that dwell at the surface of water, or those that must make contact with the air-water interface to breathe, can also be negatively affected.[47]

Nevertheless these larvicides, when used as part of a sound mosquito management strategy, can be very effective and may pose the least impact to non-target organisms and the environment.

Systemic, environmental residues prolong exposures

The impacts of mosquito spraying on pollinators can be felt long after spraying has ended. Pesticide residues on vegetation, surface waters, soil and hives, which can last from several hours to months after application, results in continued exposure for non-target organisms. Other local environmental conditions can also prolong the elevated presence of these pesticides in the environment. Johanson (1977) notes that the residual action of insecticides is increased, affecting many more bees the following day when colder nights following hotter summer days cause condensation of dew on foliage.[48] Johanson also points out that regional differences in climate can influence the toxicity of a given pesticide to bees. For example, malathion's effect on bees in warm California can be more deleterious than in cooler Washington state.

Since several pesticides are systemic in nature, meaning they are absorbed into the vegetation and expressed in pollen and nectar, have long half-lives in soil and water, and can bioaccumulate up

Nuisance vs. Disease Carrying Mosquitoes: How Communities Reach a Decision to Spray

Community mosquito-spraying varies by state and locality. Many states allow spraying by mosquito abatement districts, which operate based on perceived need, only during periods when there are public health concerns and mosquito-transmitted diseases are high. Many mosquito control programs respond to biting or sighting complaints by spraying to kill adult mosquitoes, usually at a higher threshold level than what is acceptable for public health sprays. However, with the continuous news coverage on the threat of Zika, many communities are quick to react, despite the fact that there have been no reported mosquitoes in the U.S. that are infected with the virus. Given the potential health risks and environmental impacts of adulticiding, monitoring and prevention techniques must be heavily emphasized, and spraying purely to control nuisance mosquitoes should be avoided. Public awareness should also be used to raise the bar on tolerance levels and to educate on the most effective means of mosquito management in the community and in yards. At a minimum, citizens must have the right to prevent pesticide spraying around their house or neighborhood and advance notification if spraying takes place.

Beyond Pesticides advocates that spraying should only be done as a last resort after preventive measures, and after carefully evaluating the likelihood of virus transmission, pesticide-related illnesses, and the contributing factors to a human epidemic of mosquito-borne diseases. Contributing factors to a decision to use adulticides include: the public tolerance level of mosquito-disease and exposure to pesticides, ecology of the mosquito and disease transmission, the prevalence and types of mosquito and host species found in the area, and weather patterns. Specifically, this will involve:

1. Identifying local species capable of vectoring the disease;
2. Distinguishing between nuisance mosquitoes and vector species;
3. Virus surveillance through testing of dead birds, sentinel species, and mosquito pools to see if mosquitoes in a given area are at high enough thresholds to vector the disease; and
4. Various mosquito-trapping methods that indicate densities of females, species and virus.

Often, spraying occurs in response to a high number of mosquitoes or the finding of a "positive" –either a positive mosquito pool, a positive bird or a positive human case. However, as mosquito species and vectors can vary in different areas, and as larval control is considerably more efficacious, it is critical to have a good understanding of the ecology and the stage of mosquito development prior to beginning any spray program.

Protecting Yourself and Your Community from Detected Mosquito-Borne Diseases

Pollinator protection should not be forfeited for mosquito control. Beyond Pesticides believes the ideal mosquito management strategy comes from an integrated approach that emphasizes education, aggressive removal of standing water sources, larval control, monitoring, and surveillance for both mosquito-borne illness and pesticide-related illness. These practices minimize risks to pollinators and other beneficial species. Control of disease-carrying mosquitoes can be successful when emphasis is placed on public education and preventive strategies.

- Use repellents and apply them according to label instructions. Repellents like oil of lemon eucalyptus and picaridin (derived from pepper) are the best least-toxic options that maintain high efficacy.
- Wear long sleeve shirts and long pants that are light-colored.
- Check your yard and other potential sites weekly for standing water in containers such as tires, buckets, planters and even bottle caps and piles of leaves, where mosquitoes can breed.
- Cut back any overgrown vegetation. Ensure waterways are clear of debris; eliminate pooled or stagnant waters from debris, containers, drains, and anywhere that pools water. Watch out for leaky faucets. Mosquitoes can breed in puddles the size of dimes, so keep a keen eye out for stagnant water!
- Repair windows and door screens to prevent entry of mosquitoes into homes.
- Use indigenous fish populations, like bluegills or minnows, to eat mosquito larvae in shallow waters and ornamental pools. Copepod crustaceans can also be used to eat mosquito larvae in ditches, pools and other areas of stagnant water.
- Use *Bacillus thuringiensis israelensis* (Bt), a biological larvicide that prevents mosquitoes from developing into breeding, biting adults, in standing waters that cannot be drained.
- Women who are pregnant or might become pregnant should avoid travel to areas of known Zika transmission.

Let your local council members, mayor, or state elected officials know that safe sustainable options exist. Beyond Pesticides' *Public Health Mosquito Management Strategy* and program page http://bit.ly/MosquitoManagement has a list of resources that can help you and your community safely manage mosquitoes, including least-toxic mosquito repellents, and proper clothing that can be used to keep mosquitoes safely at bay.

the food chain, non-target organisms suffer primary and secondary exposure risks from pesticide applications. Residues outside hives post-application have also been suspected as a significant source of bee mortality. That is, bees resting in front of hive entrances are exposed to lethal residue deposits.[49] In addition to contaminated pollen and nectar, residue deposits on plant surfaces can create contact exposure hazards to pollinators after initial spray application. The half-lives of pesticide residues on plant surfaces and other environmental compartments vary considerably. Malathion, for instance, has a half-life on plant surfaces of one to nine days,[50] while permethrin is upwards of 35 days.[51] Naled generally has a half-life of less than two days in soil and water, while phenothrin can stick around in soil for about 26 days.[52]

Bees and other non-target organisms drinking contaminated water, burrowing into soil, or walking across plant surfaces will inevitably come into contact with pesticide residues for days or even months after the initial spray application.

Conclusion: Can we protect pollinators and manage mosquitoes?

Pollinators are important to our food supply and ecosystem. With unprecedented losses, it is important that we minimize threats to their long-term survival. While mosquitoes can pose serious public health threats when they carry diseases like Zika, West Nile virus and others, we cannot let an overzealous response to these threats endanger pollinators, the environment and human health. Aerial and ground spraying of pesticides over large areas of land has not only been shown to inadequately control mosquito populations, but pose risks to a large variety of organisms. Common mosquito pesticides, like malathion, naled and the pyrethroids, are highly toxic to bees, other insect pollinators, as well as birds and aquatic organisms.

Widespread spraying is not a solution for these mosquito-borne diseases. These methods fail to sufficiently control mosquito populations, promote pesticide resistance, and kill other species that act as natural predators to mosquitoes. In our attempts to stave off these diseases, we inadvertently harm ourselves, non-target organisms and overall ecosystem biodiversity. We can protect pollinators and manage mosquito populations at the same time. A measured approach is needed for managing mosquitoes that first involves an understanding of the mosquito's lifecycle, reducing breeding sites, and targeting larval populations. Control of disease-carrying mosquitoes that does not endanger pollinators can be successful when emphasis is placed on public education and preventive strategies.

A fully cited version of this article is online at bit.ly/pesticidesandyou.

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