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THE EFFECT OF MOSQUITO SPRAYING ON NON-TARGET TERRESTRIAL INSECTS

A Major Qualifying Project Report

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ABSTRACT

Mosquito control procedures often use broad spectrum insecticides which may adversely affect non-target insects. This project examined the effects of aerial, barrier, and ground based ultra low volume (ULV) sprays in Massachusetts on non-target insects. Malaise traps, targeting the flying insect population, were collected in regular intervals before and after sprays, then the captured insects were sorted by order and counted. The results showed little to no effect on most non-target insects from the ground based sprays, and a temporary knockdown from the aerial spray. The Coleoptera do seem to be affected by the sprays in the short term and, for the aerial spray, in the long term.

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ACKNOWLEDGEMENTS

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BACKGROUND

Many people, upon seeing a bug, recoil in disgust or reach for a newspaper. These little creatures live mostly outside our houses and outside our notice, and we would like to keep it that way. But these organisms, the arthropods, outnumber and outweigh us. It is estimated that there are 10 quintillion (10^{19}) insects alive globally at any given time (Smithonian Institution, n.d.). Insects play a large part in our ecosystems and our lives. Some affect us positively, pollinating flowers and providing honey or, if we dare to eat an insect whole, a very nutritious meal. Some affect us negatively, spreading disease or living in and eating our homes. Although we may try to separate ourselves from these creatures, we must pay attention to them. This project focused on efforts to control a pest insect, the mosquito, and the possible negative effects on non-target populations of beneficial insects.

The Mosquito

The mosquito is an insect that we would rather do without. The characteristic whine of the mosquito's wings sets us on edge and the ever so slight pinch of its bite elicits a slap that swiftly ends the pest's life. Only a few hours later do we realize that the slap was too late when the insufferable itchiness sets in. But the mosquito is more than just an annoyance. Mosquitoes are vectors for a number of deadly diseases including West Nile Virus, Eastern Equine Encephalitis (EEE), and Malaria.

Mosquito-Borne Diseases in the U.S.

In the Northeastern United States, encephalitis-type diseases that cause brain inflammation are the most concerning. Arboviral Encephalitides are the most problematic of the mosquito-borne diseases. This group of arthropod-borne viruses includes West Nile Virus (WNV) and Eastern Equine Encephalitis (EEE). EEE, originating in songbird populations, rarely occurs in humans but when it does it is often deadly. The encephalitis causes death in a third of its human victims and brain damage in most survivors (Center for Disease Control, 2007). Horses are much more susceptible to EEE, and death often occurs within 72 hours of the first symptoms (Crans, n.d.).

The West Nile Virus is similar to EEE in that it originates in birds and can cause encephalitis in humans and horses. However, WNV is more easily spread to humans than EEE and is usually a less severe infection. With WNV, less than one percent of people show serious neurological symptoms, and about 20% of people become mildly sick for a few days to a few weeks. Most people show no symptoms at all (CDC, 2007). **Figures 1 and 2** show the U.S. activity of EEE and WNV, respectively.

Figure 1: Total Number of Human EEE Cases by State 1964-2009.
Figure from EEE Epidemiology and Geographic Distribution (n.d.)

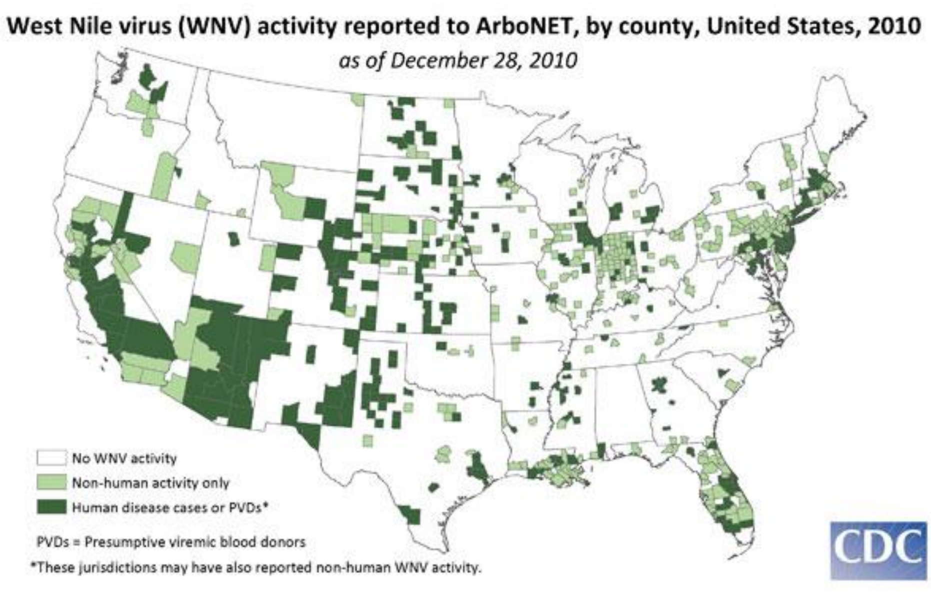


Figure 2: WNV Activity by U.S. County in 2010. Figure from West Nile Virus, Statistics, Surveillance and Control (2010)

There are many other major mosquito borne diseases in addition to those which concern the eastern U. S. Malaria is a worldwide disease that is the fifth most common cause for death among infectious diseases. Dengue fever is a potentially deadly disease that is common in tropical areas, and its incidence is increasing in Florida. Yellow fever is transmitted by the same mosquito species as dengue fever and is found in tropical areas (CDC, 2007).

Aggressive mosquito control helps reduce outbreaks of all mosquito borne diseases. Knowledge of the mosquito's habitat and life cycle facilitates better disease management.

Mosquito Biology

It is important to understand the mosquito in order to understand infected populations. There are about 150 different species of mosquito in the U.S., of which only 8 species commonly bite humans. Only the females of the species take blood meals, using the nutrients to develop eggs. When the female is ready to lay eggs, she finds stagnant water to lay the eggs in. The different species have varying egg laying strategies, some laying eggs singly and some in rafts of 200 or more. They also prefer a variety of different locations for egg laying: water filled containers, tree holes, sewage pools, tide pools, and flood plains to name a few (McCafferty, 1983).

Mosquito eggs usually hatch within two days of being laid. All mosquitoes live in the water during the larval stage (**Figure 3**). The larva come to the water's surface to breathe through a tube at the posterior end called a siphon. After molting four times over a period of a week or two, the larva pupates. The pupa now has anterior breathing tubes called trumpets. This stage of the life cycle still shows a limited mobility, diving in a tumbling motion when the surface is disturbed. After 1-4 days, the adult emerges (McCafferty, 1983).

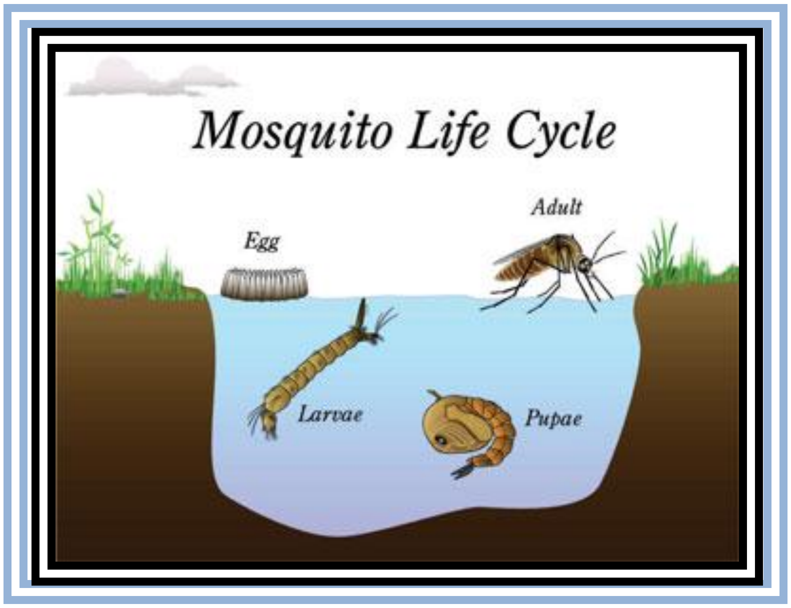


Figure 3: The Mosquito Life Cycle. Figure from San Joaquin Valley Mosquito and Vector Control (n.d.)

Mosquito Control

An entire branch of the U.S. government is devoted to monitoring and controlling mosquito populations. Adult and larval mosquitoes are collected and tested regularly for diseases, and if detected, the process of controlling the diseased mosquito population begins (Center for Disease Control, 2003). Depending on the severity of the problem, different measures are taken. Prevention focuses on reducing mosquito breeding habitats or introducing larva-eating fish into standing water. But if preventative measures fail, chemical methods are used.

Larviciding (killing the water-dwelling mosquito larvae), is used if there is no immediate human health threat. As stated at the Center for Disease Control "Guidelines for Surveillance, Prevention and Control":

> "Larviciding…is typically more effective and target-specific than adulticiding [targeting the adult mosquito], but is less permanent than source reduction…Larvicide formulations must be appropriate to the habitat being treated, accurately applied, and based on surveillance data. Accuracy of application is important because missing even a relatively small area can cause the emergence of a large mosquito brood, resulting in the need for broad-scale adulticiding (CDC, 2003, p.30)."

Adulticiding (killing the adult mosquitoes) is used when mosquito populations must be dealt with immediately to prevent disease transmission. The CDC has noted that, if used according to their labels, the adulticides "do not pose unreasonable health risks to humans, wildlife, or the environment (CDC, 2003, p31)." However, there is still concern that adulticide sprays negatively affect non-target insects, and there are no published studies which confirm or disprove this statement. This project begins to address this gap in information.

Adulticide Application Methods

When adulticiding, ground-based Ultra Low Volume (ULV) sprays are most often used. ULV sprays, applied at dusk from truck mounted sprayers (**Figure 4, left panel**), release a fog of fine droplets which float through the mosquitoes habitat. The goal of this spray is to have the droplets encounter flying mosquitoes. The droplets stay suspended in the air for a couple hours, and are only effective while airborne (Connelly & Carlson, 2009). Since mosquitoes are usually active at dusk while most other insects are dormant, this application method reduces the impact on non-target insects. The disadvantage to this method is that even a slight breeze can hinder the effectiveness of the spray or blow it off target. To help compensate, global positioning systems (GPS) and wind detection systems are used to constantly adjust the angle and power of the spray (St. Tammany Parish Mosquito Abatement District, n.d.).

Figure 4: Photographs of Ground-Based Ultra Low Volume Spray (left) and Aerial ULV Spray. Figure from St. Tammany Parish Mosquito Abatement District (n.d.)

When the problem is more widespread, the sprayers are mounted on aircraft (**Figure-4, right panel**). The aerial ULV sprays use the same basic methods as ground based applications, but it is often more effective than the ground spray because the droplets descend from above, penetrating deep woods and covering a larger area. Aerial ULV is only used when ground-based sprays are insufficient (St. Tammany Parish Mosquito Abatement District, n.d.).

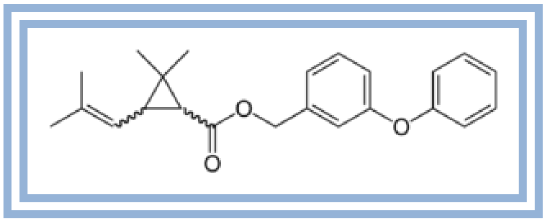
Barrier sprays are used when long term adulticide treatment is needed. This type of spray is applied in the same way as the ULV sprays, but is still effective after settling onto surfaces. The clear residue affects insects that contact it weeks later. Depending on the chemical used in the spray, it can be effective for up to 6 weeks without having to be reapplied (Adapco, 2010).

Insecticide Chemicals

The most commonly used adulticides are synthetic pyrethroids. The pyrethroid chemicals are derived from natural pyrethrins, found in the chrysanthemum flower, but are more stable in light than the natural chemicals. This allows the synthetic pyrethroids to be effective for longer periods of time. The pyrethroids interfere with sodium channels in nerve axons causing the nerves to fire uncontrollably. Mammals and birds metabolize the toxins quickly but the toxins cause paralysis and death in insects (Beyond Pesticides, n.d.).

Not all insecticides are pyrethrin derivatives. Malathion and naled are organophosphate adulticides that are applied by ULV sprays. Larvicides, such as temephos are applied to larva infested waters. Methoprene is an insect growth inhibitor which prevents the larva from properly maturing. Monomolecular films and oils are sometimes used to hinder the larva's ability to breathe at the water's surface. *Bacillus thuringiensis israelensis* and *Bacillus sphaericus* are microbial insecticides which are very target-specific.

Sumithrin and deltamethrin, the two spraying chemicals used in this project, are both synthetic pyrethroids **(Figure 5).** Sumithrin products often use the synergist, piperonyl butoxide, which increases the toxicity of the sumithrin (Cox, 2003).



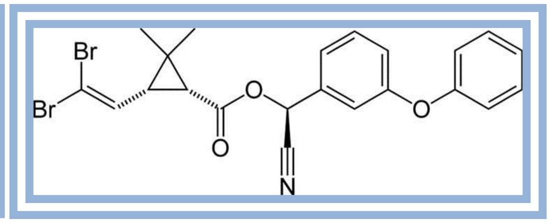


Figure 5: Chemical Structures of Sumithrin (left) and Deltamethrin.
Figure from NationMaster (2005) & About.com (2011)

Anvil 2+2, a sumithrin product, was used in the aerial and ground ULV sprays in this project. Deltamethrin, unlike sumithrin, does not use a synergist (National Pesticide Information Center, 2010). The barrier spray used in this project was the deltamethrin product Suspend SC.

Prior Insecticidal Studies

Many studies have been done to determine whether the sprays are effective and whether they affect non-target insects. Lab tests for sumithrin and deltamethrin found that the chemicals were highly toxic to honeybees and aquatic organisms. They also found that sumithrin bioconcentrates in fish over time (Cox, 2003). Inglesfield (1989) however found that lab and field toxicities were not comparable. Many studies, for example, found that bees avoid sprayed plants for a short time because of a contact repellency from the pesticides (Inglesfield, 1989). In marine environments, there were some minor effects on organisms but as Hill (2006) notes:

> [W]ith products for which realistic field studies have been reported, the effects are mostly transient and are unlikely to cause adverse changes in the populations or productivity of aquatic ecosystems.

Zhong (2007) found that aerial naled type sprays did not affect the mortality of Miami blue caterpillars while mosquitoes had a 90% mortality rate in sprayed areas.

Boyce (2007) similarly found no significant mortality among Alfalfa butterflies and honeybees in aerial pyrethrin sprayed cages. Boyce put mosquitoes in cages and found that cages with foliage cover had higher survivorship. In addition to the cages, Boyce laid out tarps to see what was killed by the spray and found only small arthropods.

Pullen (1992) did one of few ground pyrethrin spray studies using pitfall traps, which traps crawling insects. The study found that the *Carabidae* family of beetles showed significant short term drops in population, while the *Staphylinicae* family showed no susceptibility to the deltamethrin insecticide. Pullen also tested different spray plot sizes, and found that population recovery times were slower in a larger sprayed plot. Pullen then tested the effect of outside re-colonization by placing a barrier around some spray areas and found that barrier plots recovered more slowly. At the Southern Ivory Coast in Africa, Everets et al. (1985) tested three ground based pyrethroids using malaise traps and pitfall traps. Everets found that insect orders reacted differently to each of the pyrethroids. Everets also commented that pyrethrins cause hyperactivity in the insects which may cause deceptively high trapping rate and hide the spray effects.

PROJECT PURPOSE

The purpose of this project was to determine whether the synthetic pyrethrins, sumithrin and deltamethrin, applied by ground spraying to control mosquito pests at several sites in Massachusetts have any significant effect on non-target insects at the level of insect order. An aerial ULV spray offered further opportunity to study the effects of mosquito control on non-target insects.

METHODS

Mosquito Sprays

Three different mosquito control methods were examined in this study. Each of the methods was applied by normal procedures as specified on the pesticide label. The sprays were performed by Central Mass. Mosquito Control. All sprays and methods are commonly used in Central Massachusetts for mosquito control.

The ground and aerial ULV sprays both used Anvil 2+2, a sumithrin-based spray. This product is 2% sumithrin and 2% piperonyl butoxide which is a synergist to the sumithrin. Both sprays were applied at 0.02 oz per acre. The truck mounted spray was applied 30 feet from the woods. The aerial spray was applied at an altitude below 300 feet with ground wind speeds under 10 mph (Clarke, n.d.).

The barrier spray used Suspend SC, a deltamethrin product. This product is 4.75% deltamethrin and is diluted further (1 oz per gallon water) to 0.037% deltamethrin. This was applied 30 feet from the woods at a rate of 0.01 oz per acre, based on undiluted Suspend (Bayer, 2002).

Trapping the Insects

There are many ways to trap insects. Active methods include netting the insects or picking up a handful of detritus. Certain insects can be targeted using a baited trap. Light traps attract many nocturnal insects. Pitfall traps, dug into the ground, trap crawling insects. Since this project examined the effect across many orders, and the aerial pollinators are of highest concern, Malaise traps **(Figure 6)** were chosen for the collections. In this type of trap, flying insects instinctively climb upwards when they encounter the mesh sides of the tent-like trap. When they reach the top, they tire and fall into a collection jar. The jar, containing isopropyl alcohol and glycerol, kills and preserves the insects.

Figure 6: A Malaise Trap. Figure from PestControlRx (2008)

The malaise traps were set up at two sites in Massachusetts (**Figures 7 and 8**), about 50 yards apart and a few feet from the forest edge bordering an open field. The ground-based ULV traps (T1-T4) and the barrier traps (T5-T8) were set up at the edge of corn fields near Tufts Veterinary School in Grafton, MA (**Figure 7**). The aerial ULV traps (M1-M6) were similarly set up in Pratt Farm Conservation and Recreation Area in Middleboro, MA (**Figure 8**).

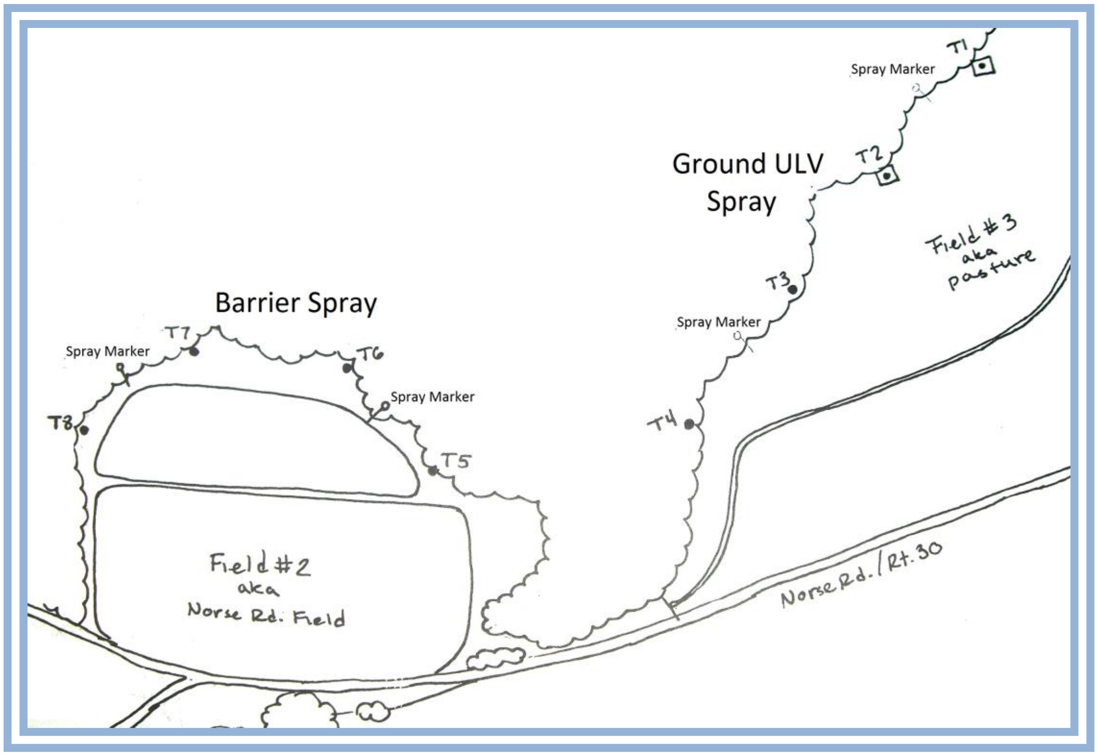


Figure 7: Trap Location for Tufts Ground Spray.

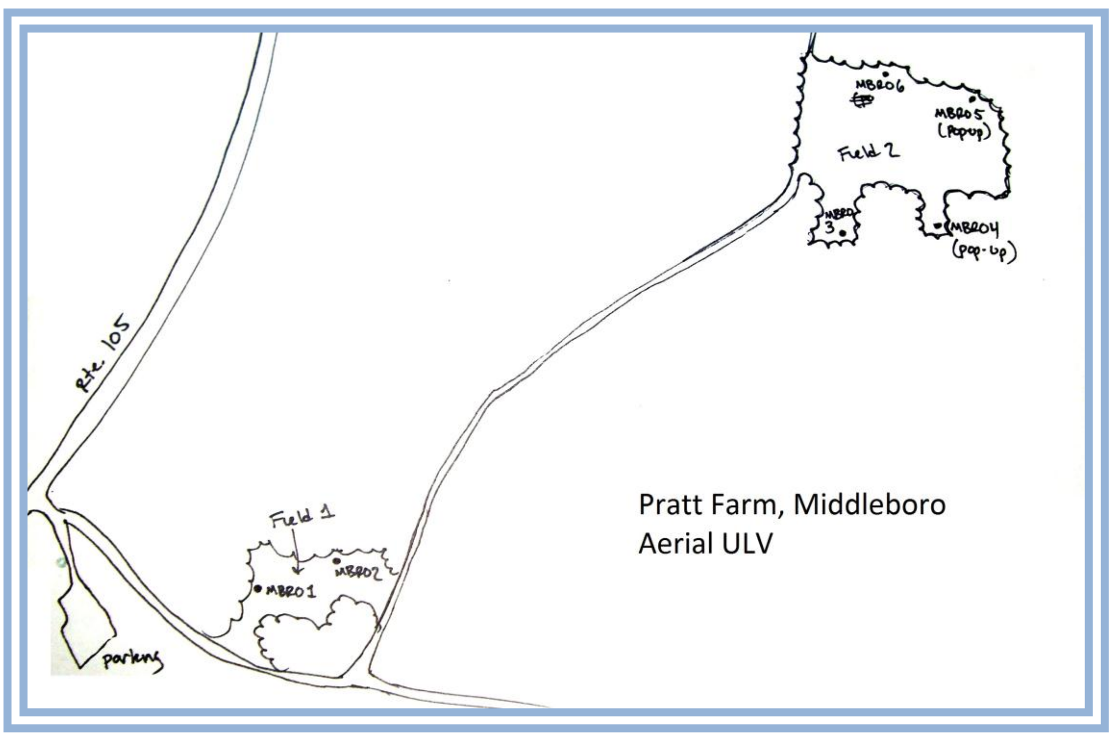


Figure 8: Trap Location for Middleboro Aerial ULV Spray.

The ground based spray traps were set up such that the two outer traps of each set of four were control traps (T1, 4, 5, 8) and the two center traps were sprayed (T2, 3, 6, 7). The aerial sprays did not have control traps except for Tufts control traps. Traps M4 and M5 for the aerial spray were smaller Malaise traps.

The captured arthropods were collected from each trap every 3-4 days and brought back to the lab for sorting and counting. One or two day collections were done immediately before and after spraying to provide higher resolution. The data was later adjusted to reflect a four day trapping period.

Insect Identification

Each collection was sorted by order and counted by the following procedure. Each jar was poured into a white dissection tray, and additional isopropyl alcohol was poured over the arthropods until they were submerged. The larger insects (> ~1.5 cm) were sorted out first. Then the remaining arthropods were randomly sampled 1/6 using a large subdivided Petri dish. A section was randomly chosen and the arthropods in that section were removed and placed in a smaller Petri dish. The sampled arthropods were sorted using a pipette to extract the smallest insects. A swirling motion was used which caused the small gnats to separate from the rest of the insects. This made it much easier to count the small arthropods and is suggested in future studies. All arthropods were saved in labeled vials for future studies.

Insects were initially identified using an online identification key (Ramel, n.d.) and a field guide (Evans, 2007). After experience was gained in identification, arthropods were identified by several distinct features (**Table 1**).

Order*	**Common Name**	**Identification**
Diptera	Flies, Gnats, Mosquitoes	Two wings, Second pair of wings replaced by halteres
Hymenoptera	Bees, Wasps, Ants	Body pinch before abdomen, hard body
Lepidoptera	Moths, Butterflies	Broad scaled wings, curled proboscis
Homoptera	Leafhoppers, Aphids	Greenish rice shaped body *or* soft body with angular legs
Hemiptera	True bugs, Stink bugs	Hardened outer wings, triangular shape
Coleoptera	Beetles	Hardened shell, round
Psocoptera	Wood lice	Three visible segments, almost ant-like, soft body
Dermaptera	Earwigs	No wings, pincers on back end
Odonata	Dragonflies, Damselflies	Thin elongated abdomen, four long wings
Orthoptera	Grasshoppers, Crickets	Muscular hind legs
Neuroptera	Lacewings	Long thin body; wings with net like veins
Trichoptera	Caddis flies	Hairy wings held tent like over body
Mecoptera	Hanging Fly, Scorpion Fly	Long proboscis, some have scorpion tail
Collembola	Springtails	Small blue body
Thysanoptera	Thrips	Small body with distinct feather like wings
Non-Insects		
Araneidae	Spiders	Two segments; 8 legs; biting mouthparts
Opiliones	Harvestmen	Oval body with no clear segments; 8 legs
Acari	Mite	Small orange dots; 8 legs
Pseudoscorpion	Book Scorpion	Resembles a scorpion missing only the tail

Table 1: Insect Identification Guidelines Used in this Project.
*Only insect orders found in this study are listed.

RESULTS

The purpose of this project was to determine whether synthetic pyrethrin mosquito sprays adversely affect non-target arthropod populations. Malaise traps were set up in sprayed and control areas. The insects were collected from the traps every three to four days preceding and following the application of aerial ULV, ground ULV, and barrier sprays by Central Mass. Mosquito Control.

Population Graphs

This section will go through the populations of each of the major orders over time as the traps were sprayed. The ground ULV spray was performed on traps T2 and T3 on 7/28/2010 and 8/11/2010. The barrier spray was performed on traps T6 and T7 on 8/11/2010. Traps M1-M6 were all set in the aerial spray zone. The aerial spray was performed on 8/5/2010 and 8/6/2010. For the Tufts traps graphs, the control traps are shown in the figures in blue, and the sprayed traps are shown in orange. Spray dates are denoted by a vertical dotted line.

Hymenoptera

The *Hymenoptera* and *Lepidoptera* were of highest concern since they are key pollinators. Wasps also help control pest populations.

In the ground ULV spray (**Figure 9, left**), the control and spray groups had similar fluctuations in population. At the end of trapping, the spray groups had higher populations than at the beginning of trapping whereas the control groups had similar populations to the pre-spray collections. The barrier spray (**Figure 9, right**) also found similar changes between the control and spray groups. There was a spike right before the spray in T7 (also seen to a lesser degree in T2) that was a group of queen ants. The aerial ULV spray (**Figure 10**) had a spike at nearly the same time that was also because of queen ants. Trap M6 showed a significant decrease in *Hymenoptera* population but none of the other traps showed this trend.

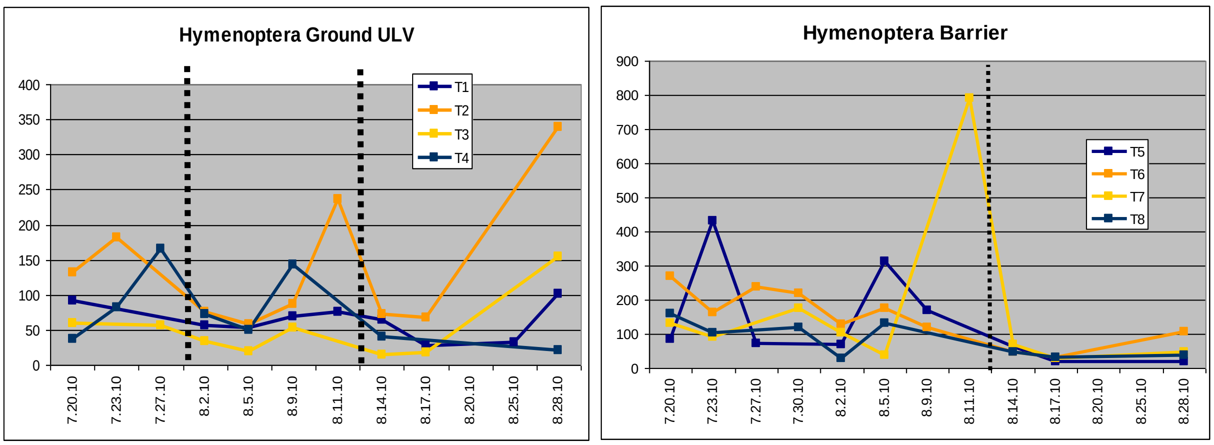


Fig. 9: *Hymenoptera* Population for Ground ULV Spray (left) and for Barrier Spray (right).

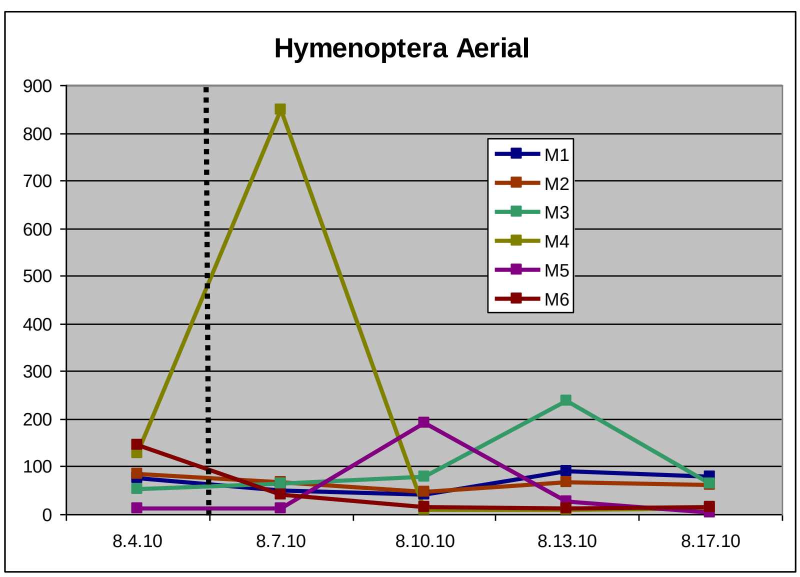
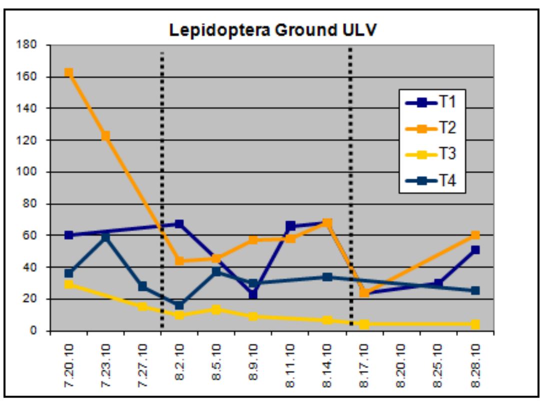


Fig. 10: *Hymenoptera* Population for Aerial ULV Spray.

Lepidoptera

The *Lepidoptera* are the other major pollinators.

In the ground ULV application (**Figure 11, left**), the sprayed group decreased in population at each spray date, and the final population of butterflies was lower at the end of trapping than it was before trapping. The control traps showed some decrease around the same times but to a lesser degree. The barrier traps (**Figure 11, right**) showed a similar decrease around the same time and the controls had lower populations at the end of trapping. All of the traps showed similar patterns in population change for the barrier spray. The aerial spray (**Figure 12**) produced slight drops in population in most traps which recovered in a week. Trap M6, which had a higher population to begin with, seriously dropped in population after the spray and did not recover.



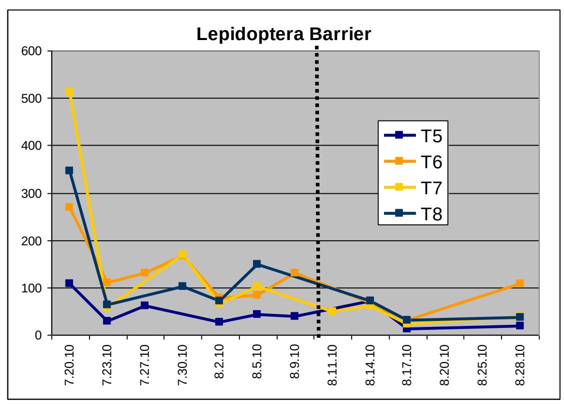


Fig. 11: *Lepidoptera* Population for Ground ULV Spray (left) and for Barrier Spray (right).

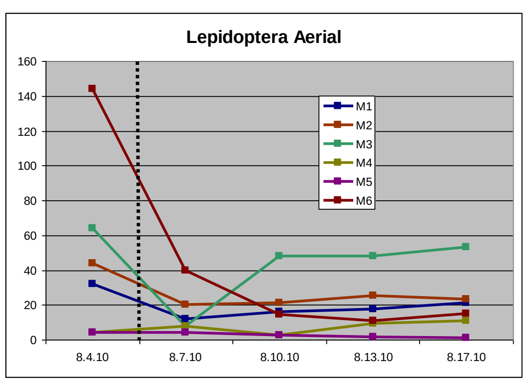
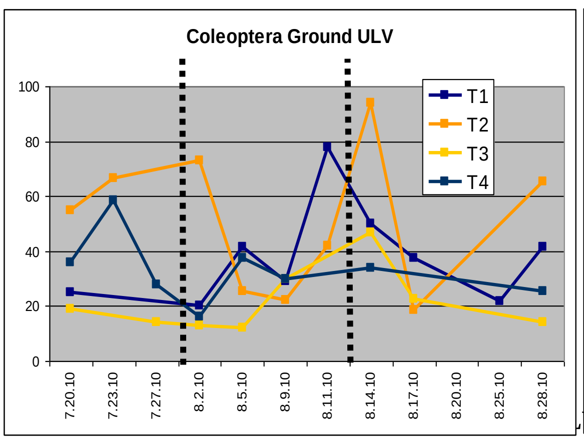


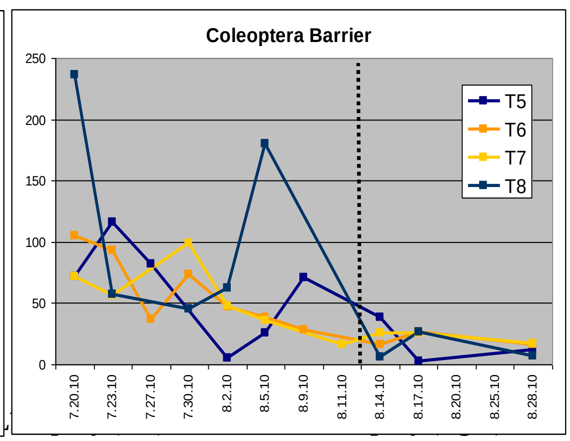
Fig. 12: Lepidoptera Population for Aerial ULV Spray.

Coleoptera

Many *Coleoptera* play an important role in breaking down dead organic matter. Some other beetles control pest populations or help pollinate flowers.

In the ground ULV spray (**Figure 13, left**), there was a delayed drop in population after both sprays that was not seen in the control groups. In each case, except for T3 in the second spray, the populations quickly rebounded. The barrier trap populations (**Figure 13, right**) were highly variable before the spray. Sprayed traps showed no change in population at the spray date. The aerial spray (**Figure 14**) showed a steady decrease in population across all spray traps after the spray, while control populations were variable throughout this time period but overall neither increased nor decreased.





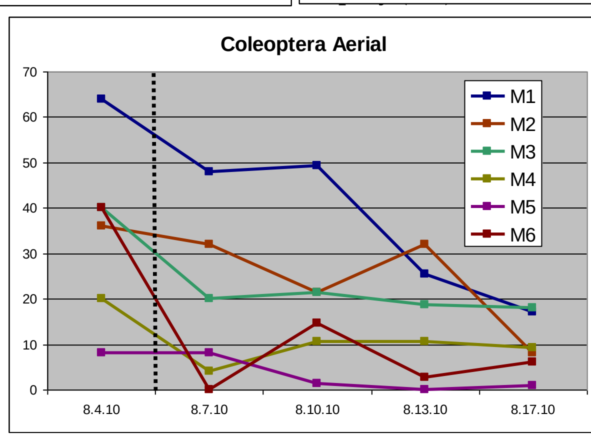


Figure 14: Coleoptera Population for Aerial ULV Spray.

Homoptera

Homoptera are generally considered plant pests but nonetheless provide an important food source for many other arthropods.

In the ground ULV spray (**Figure 15, left**), the control and sprayed groups show similar patterns of population change. All traps saw a decrease in *Homoptera* after the first spray. During the second spray, the biggest decrease in population was found in T1, a control trap. In the barrier spray (**Figure 15, right**), T6 had a large spike in *Homoptera* population that dropped after the spray. T7, the other spray trap, showed a slight increase in population after the spray. Both control groups decreased in population. During the aerial spray (**Figure 16**) most *Homoptera* populations dropped slightly whereas the control traps at tufts showed an increase in population over the same time.

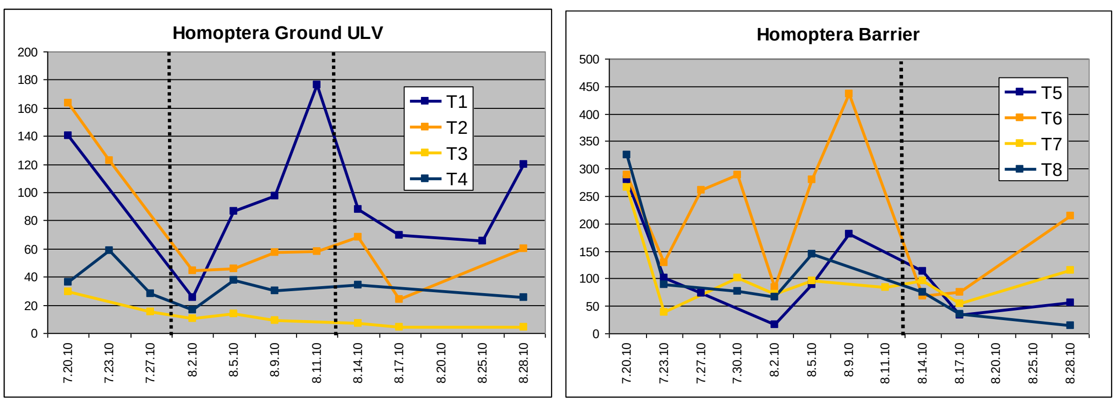


Fig. 15: *Homoptera* Population for Ground ULV Spray (left) and for Barrier Spray (right).

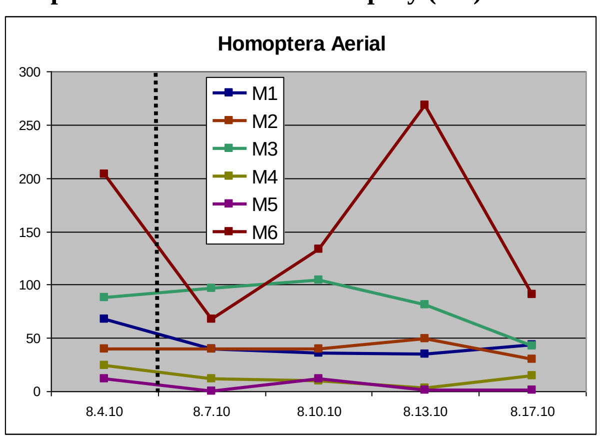


Figure 16: *Homoptera* Population for Aerial ULV Spray.

Shannon Diversity

The Shannon Diversity Index quantifies the diversity of the insect populations that were collected. The index is based on the number of orders in the population and how even each of the orders' populations are (relative population) (Carlsbad High Science Department, n.d.). The index is calculated by the following equation:

$$H = -\sum P_i(\ln P_i)$$

P_i= Proportion of each orders' population in sample
H= Shannon diversity

This index will not show a change if all populations drop evenly, which is why population graphs were also included.

In this type of analysis, the ground-based ULV spray showed no difference between the control and spray groups. The barrier spray showed a slight drop in the control groups compared to the spray groups, but there was great variability in data before the spray. The aerial spray showed a significant drop during the spray which was followed by a recovery within a week. There is a drop in diversity on the last collection of the aerial spray traps.

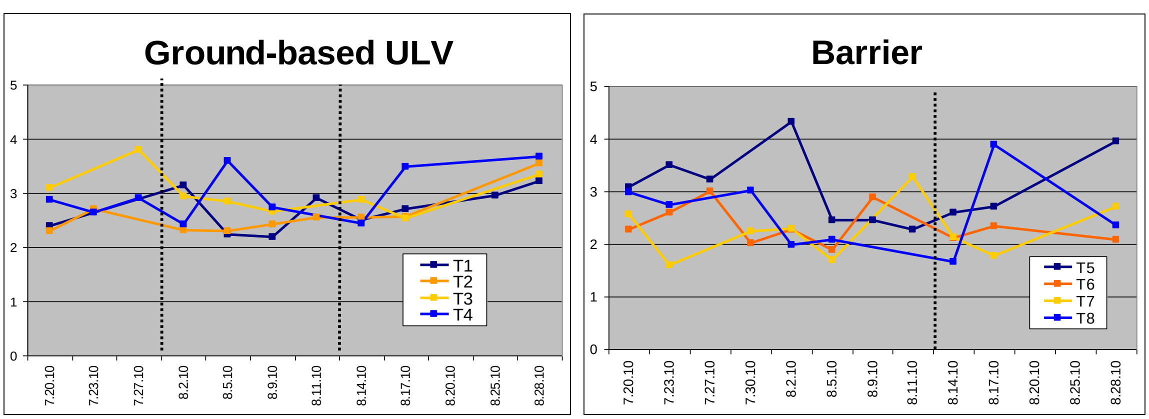


Fig. 17: Shannon Diversity Index for Ground ULV Spray (left) and for Barrier Spray (right).

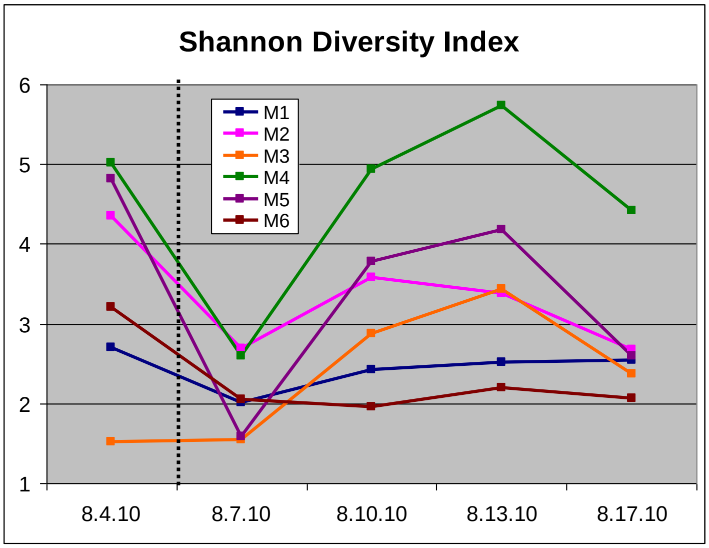


Figure 18: Shannon Diversity Index for Aerial ULV Spray.

DISCUSSION

Overall, this study found that there is little to no ecological risk on non-target insect populations due to mosquito spraying, as long as the sprays are correctly applied. The Shannon diversity index showed a significant drop in diversity for the aerial spray but it recovered in a week. There was a secondary drop in diversity on the last trapping of the aerial traps which may have been natural variation or a second generation effect. The other diversity indexes showed no significant diversity changes related to the spray. The population graphs often showed great variability in insect populations in both the control and spray groups. This made it difficult to distinguish between spray effects and naturally occurring changes in population.

Coleoptera and *Hymenoptera* showed the greatest susceptibility to ground ULV sprays compared to the control. In each case both control traps dropped as well as the sprayed traps (during both sprays) but to a lesser degree. The Shannon index did not indicate any significant change in biodiversity. *Hymenoptera* and *Homoptera* appeared to be most susceptible to the barrier spray but there were population spikes in both of these populations before the spray (T7 Hymen.; T6 Homo.) which may have naturally dropped. The sprayed traps without the spike showed no significant drops compared to the control. The Shannon index showed a slightly more negative trend in diversity compared to the control. All major orders seemed to be at least mildly affected by the aerial spray. Each of the orders dropped initially in population but most recovered to levels comparable to the pre-spray populations. The order *Coleoptera* was the only one that showed a continual downward trend to the end of trapping. The control traps showed a variable but mostly upward trend during this time period. Future studies should pay special attention to *Coleoptera* populations in aerial sprays.

Of the sprays, the aerial spray seemed to have the biggest effect, whereas the barrier spray had the smallest effect on populations and diversity. This was likely due to the larger area of spraying and from the droplets falling down onto the insects and vegetation. There was likely some comeback from migration into the spray area as Pullen (1992) noticed in his netted spray area experiment. It is also likely that the aerial spray simply contacted more arthropods in an area than ground sprays. In this study, insect populations seemed localized with very little crossover between traps. These localized populations, along with natural population variation, also made it hard to directly compare traps even when they were set only 50 yards apart. Everets et al. (1985) noted that pyrethroids cause hyperactivity in arthropods which may have masked the population drop in the short term. Regardless, long term data showed that populations either recovered or were not affected by the spray. Hill (2006) and Boyce (2007) both found that realistic use of the pesticides results in little long term effect on non-target insects. This study confirms their results.

This study showed that mosquito spraying using deltamethrin or sumithrin has no visually significant long term effect on non-target insects. Trapping measures activity as well as population as more active insects will more often encounter the traps. Natural variation in population and activity, and possible hyperactivity due to the sprays may have masked the effects of the sprays. Fortunately, this year was a hot dry summer with few rainstorms and little temperature variation which in past years of trapping cause great variability in population. To help counteract the variability, caged insect tests like

Boyce's study (2007) may produce less realistic results but allow for a more controlled experiment. It is possible that drops in control traps around spray dates were not due to natural variation but spray drift. It is suggested that all future experiments test for insecticide levels at each test site. Too few traps were used in this study for good statistical significance. Future studies should set up a larger number of traps to obtain statistically significant data. Studies using other trapping methods would be useful. Malaise traps only trap flying insects that climb up when they hit a barrier. Ground trapping needs to be done to collect data from the ground crawling insects where the pesticides settle. Light trapping would collect light attracted insects, like moths, which would be active during the spray and therefore susceptible to the effects. Other traps such as bait traps may also be useful if a certain order is found susceptible to a certain spray.

It is difficult to do a controlled experiment in the field as there are many uncontrollable factors which may skew results. There were not enough traps in this study to produce statistically significant results, but visually the graphs show little difference between spray groups and control groups. The aerial spray produced a small knockdown of population which quickly recovered. This study concludes there is little to no ecological risk from barrier deltamethrin sprays or sumithrin ULV sprays with respect to the short or long term populations of non-target insects with the possible exception of *Coleoptera* in aerial sprays.

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