STRATEGIES FOR THE APPLICATION OF LARVICIDES TO CONTROL MOSQUITOES IN RESPONSE TO WEST NILE VIRUS IN CONNECTICUT: Supplement to West Nile Virus Response Plan

Connecticut Department of Energy and Environmental Protection

Introduction

A successful mosquito management program should entail a comprehensive, integrated approach to managing mosquitoes, not unlike any Integrated Pest Management (IPM) program. There are several components to a successful program including: 1) surveillance and mapping of mosquito-breeding areas; 2) monitoring of larval and adult mosquito populations; 3) source reduction and a strong education campaign to eliminate or remove local sources of mosquitoes; 4) water management in natural and artificial wetlands, where allowable, to eliminate areas that produce mosquitoes and concurrently encourage biological control by larvivorous predators (e.g., fish); and 5) control of larval and adult mosquito populations using approved pesticides. The goal is to effectively use a variety of these tools and not rely heavily on any one of these components. If done in an integrated fashion, a program can be effective at managing mosquitoes (while minimizing non-target impacts), efficient, economical, and can also reduce the public health risk of West Nile virus (WNV), other mosquito-borne diseases and related medical issues arising from excessive mosquito bites. The Connecticut Mosquito Management Program, an interagency cooperative of the Department of Energy and Environmental Protection (DEEP), the Department of Public Health (DPH), the Connecticut Agricultural Experiment Station (CAES), the Department of Agriculture (DAG), and the University of Connecticut, Department of Pathobiology and Veterinary Science (UConn), uses such an approach to manage mosquitoes and reduce the public health risk from mosquito-borne diseases.

If source reduction or managing water levels in mosquito-producing habitats is not feasible (e.g., swamps, vernal pools), and the sites are accessible, the judicious use of pesticides designed to control mosquito larvae ("larvicides") can be an efficient method of control. Larviciding involves the application of state and federally-registered pesticides to aquatic habitats where mosquito larvae thrive. The larvae are concentrated in relatively small, defined areas where they filter feed on detritus and organic matter in the water. According to the National Centers for Disease Control and Prevention, the objective of the larval mosquito control component of an effective Integrated Vector Management (IVM) program is to manage mosquito populations before they emerge as adults (http://www.cdc.gov/westnile/resources/pdfs/wnvGuidelines.pdf). Larviciding is much more efficient and cost-effective than more large-scale treatment (spraying) for adult mosquitoes. An effective larviciding program can reduce adult mosquito populations by ninety percent or more. However, larval control alone may not attain the levels of mosquito reduction needed to maintain WNV risk at low levels, and must be done in conjunction with control of adult mosquito populations. In a WNV outbreak situation, larval control compliments adult mosquito management measures by preventing new vector mosquitoes from emerging. Larval control alone will not stop a disease outbreak once virus amplification has reached levels to cause human infections because vector adult mosquitoes are not affected by larvicides.

Mosquito Biology and Larval Development

Currently (2013) Connecticut has 52 species of mosquitoes. A manual, published by the CAES, provides an identification key to Connecticut mosquitoes and descriptions of their ecology and vector competence (http://www.ct.gov/caes/lib/caes/documents/publications/bulletins/b966b996.pdf). Some mosquito species are very specific in their host-seeking and egg-laying (oviposition) preferences while others can be grouped into more general categories. Some species, like those of the genus *Culex* or *Anopheles*, will spend the winter months ("over-winter") in the adult stage, seeking refuge in barns, basements, caves and rock crevices. Others, such as those of the genus *Ochlerotatus, Aedes* or *Psorophora*, over-winter in the egg stage. A few will even over-winter under water (even ice) in the larval stage (e.g. *Coquilletidia* and *Culiseta).* When considering ovipositing site preference, *Ochlerotatus, Aedes* or *Psorophora* species lay their eggs on moist substrate, such as mud-bottomed depressions in a salt marsh, wet leaf litter in a woodland pool, or the inside of a discarded tire casing. These are generally known as "floodwater" species. After an incubation period of several days, the eggs may hatch after being inundated with water such as heavy rainfall or extreme high ("spring" or perigee) tides in coastal areas. *Culex* and

Anopheles species on the other hand will lay their eggs, either individually or clustered in an egg "raft", directly on a stagnant water surface (e.g., abandoned swimming pools, sewage lagoons, containers holding water). Larger open bodies of water (ponds), even when covered with algae or appearing "stagnant", generally do provide habitat conducive to producing mosquitoes.

Larval and pupal development is directly related to water temperature and day length (photoperiod). In early spring when water temperatures are cooler, larval/pupal development may take 1-2 months. However, during the summer months, when water temperatures are considerably warmer, adult mosquitoes may emerge as early as 5-10 days after hatching. In Connecticut, mosquito larvae are generally found from late March through mid-October (although, as mentioned, some species overwinter in the larval stage). Timing of larval inspections, therefore, should be related to the time of year and time of flooding as this could determine what control measures to be taken. In tidal wetlands, flooding of salt marsh mosquito sites and subsequent hatching of eggs (primarily of *Ochlerotatus sollicitans, O. cantator* and *O. taeniorhynchus)* is triggered by lunar tidal events (spring tides) that flood the upper or "high" marsh (dominated by salt hay) during the full and new moon phases and by heavy rainfall. Larvae are generally found from mid-May through September.

In freshwater swamps, marshes, river floodplains and woodland (vernal) pools melting snow and high water tables in early spring trigger hatching of eggs that were deposited the previous autumn. Larvae are generally found from mid-March to early May with first emergence from mid- to late May. Subsequent ovipositing and populating by other mosquito species can take place as these sites dry out and become reflooded by heavy rains throughout the summer. Grassy swales, ditches, ruts and areas intermittently flooded by rainfall (again, that can retain water for 5-10 days) are prime ovipositing sites for several *Ochlerotatus*, *Aedes* and *Psoraphora* species.

Permanently flooded marshes dominated by floating mats of vegetation such as cattail, sedges or water willow can be breeding areas for species such as *Coquilletidia perturbans.* The larvae and pupae of this unique species obtain oxygen by piercing and attaching to the underwater roots and stems of these plants, making larval inspection and control very difficult. Noteworthy is that in most cases, a permanent, open body of water (e.g., pond, lake, stream) is not conducive to producing mosquitoes. They do not provide adequate ovipositing sites and most often will have an aquatic community of natural predators.

Natural and artificial cavities or containers such as tree holes or tire piles can be ovipositing sites for *Ochlerotatus, Aedes, Culex* and *Anopheles* species. Stagnant, organically-rich sites that retain water for a significant amount of time (e.g., catch basins, sewage lagoons, animal watering troughs, ditches or rain gutters clogged with debris, abandoned swimming pools, boats, tarps and other containers that collect rain water) offer continuous ovipositing sites for *Culex* and *Anopheles* species.

Larviciding Recommendations

If eliminating the source of mosquito production is not physically possible or allowed by regulation (e.g., altering natural wetlands), the use of an approved larvicide can provide effective control. Anyone considering the commercial application of any pesticide on municipal or private property must be certified and registered with the Connecticut DEEP, Pesticide Management Division. Information on applicator certification and registration of pesticides can be found at http://www.ct.gov/deep/cwp/view.asp?a=2710&q=324266&deepNav_GID=1712%20.

A municipal larvaciding program for control of mosquitoes should include *Culex* breeding habitats (catch basins and similar stagnant sites) as well as floodwater habitats where accessible. On public and private school property, certain restrictions apply for the application of pesticides per PA 07-168 (http://www.cga.ct.gov/2007/ACT/PA/2007PA-00168-R00HB-05234-PA.htm). School officials and the applicator should be familiar with the conditions of this Act.

There are only a few larvicides that are registered and available in Connecticut for licensed applicators and homeowner use. A more detailed description of pesticides used for larval mosquito control is available from the U. S. EPA (http://www2.epa.gov/mosquitocontrol/controlling-mosquitoes-larval-stage). No individual larvicide will work effectively and consistently in all habitats and under all conditions where mosquitoes thrive. As in any IPM program, is it important to have many options available to contend with variations in habitat, weather and for pesticide resistance management. Proper training of field applicators is required to properly identify larval production sites and implement the appropriate management option (source reduction or larvicide) for that site. A flowchart showing larvaciding options is found in Figure 1. By Federal law, all pesticides must be used according to label specifications.`

For catch basins, stagnant retention basins and other *Culex* habitats the following is recommended:

- Products containing the biological agents *Bacillus sphaericus* (Bs) or *Bacillus thuringiensis* var. *israelensis* (Bti). *B. sphaericus* comes in a granular, wetable powder, slow release briquette or water-soluble packet formulation. Also available are dual-action formulations of Bs and Bti. The bacterial strains in Bs are more specific to *Culex* larvae than Bti. Bs and Bti are bacterial agents and must be ingested by the filter-feeding mosquito larvae and as such, these products will not affect mosquito pupae or adults. The use of Bti or Bs on municipal or individual homeowner property does not require any special licensing by the CT DEEP.

- S-methoprene (trade name Altosid®). Methoprene is an insect growth regulator and comes in a variety of liquid, granular, pellet and briquette formulations. If using Altosid for catch basins a pellet, 30-day or 150-day briquette formulation is recommended. Methoprene will not affect pupae or adults. Connecticut regulations specify that the use of methoprene requires that the applicator be licensed and a permit be obtained from the DEEP prior to application. Also, PA 13-197 prohibits certain uses of methoprene in the coastal zone (http://www.cga.ct.gov/2013/ACT/PA/2013PA-00197-R00HB-06441-PA.htm).

- The biological agent *Saccharopolyspora spinosa* or Spinosad (trade name Natular®). Spinosad comes in a variety of formulations and works on all mosquito species. Natular will not affect mosquito pupae or adults. Although it is a bacterial agent, because of its mode of action, Connecticut regulations specify that the use of spinosad requires that the applicator be licensed and a permit be obtained from the DEEP prior to application.

- The Larvasonic® Acoustic Larvacide Device emits sound waves to kill mosquito larvae (www.newmountain.com). The Larvasonic works on all species of mosquitoes. Mosquito larvae must be present for the Larvasonic to be effective and as such, requires more intensive larval surveillance. Since this device works by emitting sound waves, it is not considered a pesticide and therefore is exempt from pesticide regulations.

For ditches, intermittent wetlands, salt marshes and other floodwater areas, the following is recommended:

- If mosquito larvae are present, apply a liquid, granular or briquette formulation containing the biological agent Bti (several brands available). Single brood granular and liquid fornulations only control larvae that are present and must be reapplied to every mosquito brood. Briquette formulations are slow release formulations that can provide 30 or more days of control.

- S-methoprene (trade name Altosid®). See above.

- The biological agent Spinosad (trade name Natular®). See above.

- The Larvasonic® Acoustic Larvacide Device. See above.

- If larvae and/or pupae are present a monomolecular surface film or MMF (i.e., Agnique®) can be used. Note: the use of Agnique in Connecticut requires that the applicator be licensed and a permit be obtained from the DEEP prior to application. Agnique is not registered for homeowner use.

Connecticut's Mosquito Management Program

Organized mosquito control has existed in Connecticut since 1902. With its beginnings at the CAES, mosquito control was later housed in the DPH for many decades before it was legislatively eliminated in 1992. The staff was moved to the DEEP in 1992 as a newly formed Wetland Restoration Unit with no distinct mosquito control duties. Now, instead of coast wide mosquito control, tidal wetland restoration was undertaken, with source reduction to reduce mosquito-breeding sites (via a technique called

Open Marsh Water Management or OMWM) only a secondary benefit of restoration efforts. In 1997, the year following an epizootic of EEE in southeastern Connecticut, funding was allocated under PA 97-298 to create a smaller yet organized Mosquito Management unit in the DEEP Wildlife Division to complement the existing Wetland Restoration Unit. Today, as mentioned earlier, Connecticut's statewide Mosquito Management Program (MMP) is a multi-agency effort of the CT DEEP, DPH, CAES, DAG and UConn. Following an IPM approach, each agency has specific tasks which are described in greater detail on the state's MMP web site: www.ct.gov/mosquito. Specifically, the DEEP's Wetland Habitat and Mosquito Management (WHAMM) Program performs operational mosquito control (i.e., mosquito inspections, pesticide applications, OMWM) on coastal state-owned properties (Table 1), but also provides technical guidance and education to municipalities and homeowners concerning mosquitoes and their control, and tidal and freshwater wetland restoration throughout the state. The WHAMM Program has also inspected and applied larvicides the Great Meadows Unit of the S. B. McKinney National Wildlife Refuge under a special use permit of the USFWS.

Additional Provisions Necessary to Meet the Requirements of Sec. 7 of Public Act No. 13-197

The DEEP will not apply or approve the application of methoprene in the coastal zone as defined in subsection (a) of section 22a-94 of the Connecticut General Statutes. Exceptions include municipalities specifically authorized in PA 13-197 and under such instances when recommended by the Commissioner of Energy and Environmental Protection in consultation with the Commissioner of Public Health as necessary to address a disease threat identified by the CAES and DPH. The use of resmethrin (not a larvicide) by DEEP will be similarly restricted.

Historic Use of methoprene and other mosquito pesticides in Connecticut

Table 2 lists a summary of mosquito control pesticides used by the DEEP WHAMM Program since 1998. The amounts reported reflect the total pounds of active ingredient of each product applied throughout the state per year. Of the sites listed in Table 1, Barn Island, Harkness, Rocky Neck, Hammonasset, Silver Sands, S. B. McKinney NWR and Sherwood Island tend to receive the most attention in terms of inspections and larvicide treatments because of the habitat, consistency and intensity of mosquito production, use by the public and proximity to populated areas. Formulations of methoprene that can provide longer periods of control (e.g., briquettes) have been used in areas that may be hard to reach (and as such, may not be able to be inspected as easily or frequently as other sites), or are further away (thus taking longer for inspectors to get to every site). Given the short window of opportunity to apply larvicides in the summertime after a flooding event, the current level of staffing of the WHAMM Program is often not adequate to effectively inspect and treat every mosquito breeding site; another reason why residual formulations of pesticides are used to ensure a site is treated if an inspector can't physically get to all sites. Since methoprene use is now restricted in the coastal zone, additional staff could be added to allow the WHAMM Program to inspect these sites more frequently to enable the effective use of non-residual biological pesticides (e.g., Bti, Bs).

The long term goal of the WHAMM Program on these coastal properties is to perform source reduction via OMWM to minimize or eliminate sources of mosquitoes and enhance or restore wildlife habitat in tidal wetlands. This process takes time to implement (obtain permits, secure funding, coordinate logistics, work within permit restrictions such as breeding bird seasons), however the WHAMM Program has successfully implemented OWMW on many coastal sites, eliminating the need to apply larvicides in those areas. The WHAMM Program is working towards implementing OMWM on all coastal mosquito-breeding areas where feasible.

Reporting of methoprene and resmethrin use

The use of methoprene as a larvicide is governed by the aquatic permit requirements in Sec. 22a-66z of the General Statutes. As such the pesticide program of DEEP issues permits and receives use reports for those permits and from commercial applicators. DEEP use of methoprene larvicide is exempt from permit requirements, however DEEP personnel are certified applicators and report their annual use to the pesticide program. These data are collated and posted on the pesticide program page of the DEEP web site.

The first year of such reporting was 2013 for data from 2011 and 2012 http://www.ct.gov/deep/cwp/view.asp?a=2710&q=534352&deepNAV_GID=1712 .

Resmethrin is not used as a larvicide and as such does not require a permit. It is however being phased out voluntarily by the manufacturers and the only formulation still registered is a mosquito adulticide classified for restricted use. As a result, use is by certified applicators and annual use is reported to the DEEP pesticide program and shall be posted on the pesticide program page of the DEEP website.

A pilot program to evaluate the retail sale and use of methoprene and resmethrin

A study to evaluate the sale and use of these pesticides will be considered following the completion of an ongoing study on the potential impacts of these substances on Long Island Sound lobsters. Design of a study on retail sale and use would involve requiring manufactures and retailers to report amounts sold in the general vicinity of the coastal area. Agency authority to require reporting will need to be expanded. Evaluating pesticide use on private properties will require developing and implementing a labor-intensive study to obtain data on how, when, and where specific pesticides are applied subsequent to purchase. A market research firm or University will need to be contracted to design and conduct a statistically based study. The cost of this study is anticipated to be approximately $250,000.

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Table 1. Coastal state-owned properties that may be inspected for mosquitoes by the DEEP WHAMM Program. (* denotes property owned by the US Fish and Wildlife Service).

Property	Town	Habitat
Barn Is. Wldlf Mgt. Area (WMA)	Stonington	salt marsh, vernal pools
Six Penny Is.	Groton	salt marsh
Bluff Point State Park	Groton	salt marsh
Fort Griswold/Fort Trumbull	New London/Groton	rainwater
Harkness State Park	Waterford	salt marsh/rainwater
Rocky Neck State Park	East Lyme	salt marsh
Great Is. WMA	Old Lyme	salt marsh
Ragged Rock WMA	Old Saybrook	salt marsh
South Cove/Plum Bank	Old Saybrook	salt/brackish marsh
Hammock River	Clinton	salt/brackish marsh
Hammonasset State Park	Madison	salt marsh/rainwater
Great Harbor Marsh WMA	Guilford	salt marsh
Branford River	Branford	brackish marsh
Pine Orchard Marsh	Branford	brackish marsh
Quinnipiac River WMA	North Haven	brackish marsh
Silver Sands State Park	Milford	brackish marsh
Wheeler Marsh WMA	Milford/Stratford	salt/brackish marsh
S.B. McKinney NWR*	Stratford	salt marsh
Sherwood Is. State Park	Westport	salt marsh/rainwater

Table 2. Summary of Mosquito Control Pesticides Use by the CT DEEP (1998-2013).

Year	Larvicides (lbs. active ingredient)				
	Bti	**Bs**	**methoprene**	**surface film**	**spinosad**
1998	1911	0	0.03	0	
1999	4977	0	2.8	100 oz	
2000	1960	0	12.9	16 oz	
2001	1560	680	3.4	0	
2002	265	358	0.9	60 oz	
2003	210	1220	3.3	112 oz	
2004	360	2640	3.8	96 oz	
2005	680	960	4.5	32 oz	
2006	345	1270	4.1	32 oz	
2007	400	840	6.2	32 oz	
2008	500	960	5.7	32 oz	
2009	2080	1217	14.2		
2010	344	472	2.1		
2011	200	498	1.6		
2012	304	242	2.83		0.1
2013	459	478	0.43		0.92

Year	Adulticides (lbs. active ingredient)				
	malathion	**resmethrin**	**sumithrin**	**bifenthrin**	**permethrin**
1998	29.4	2.23	0.31		
1999		16.2	0.31		
2000		12.56			
2001					
2002					
2003		0.03	0.21		
2004		1.3			
2005					
2006		2.43		16	2.8
2007		1.7			0.27
2008		3.71		0.01	0.24
2009		3.02		0.08	0.1
2010					
2011		0.05		0.03	0.06
2012					
2013		0.95		0.04	0.04

Figure 1. Larvaciding Alternatives for Municipal Mosquito Management

For information on applicator licensing and exams or aquatic permits: www.ct.gov/deep, "permits & licenses"
For pesticide-related or regulatory questions contact the DEEP Pesticide Division, 860-424-3369
For technical assistance on mosquito control contact the DEEP Wetland Habitat and Mosquito Management Program, 860-642-7630