Update to the 1998 Mosquito Control Program Generic Environmental Impact Report (GEIR) EOEEA #5027

August 14, 2009

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Introduction.

The goal for this document is to update the existing comprehensive 1998 Mosquito Control Generic Environmental Impact Review (hereafter GEIR), and in particular, address issues outlined in the Certificate of the Secretary of Energy and Environmental Affairs for the Commonwealth of Massachusetts on the GEIR, EOEEA #5027, issued January 16, 2009 (hereafter, Secretary's Certificate; **Appendix 1**). These issues are: (1) to evaluate past and current mosquito control practices; (2) to identify and act upon new information derived from the monitoring activities conducted by the Proponent (State Reclamation and Mosquito Control Board, hereafter SRMCB) and others; (3) to improve the Proponent's existing freshwater, open marsh, and chemical mosquito control activities based upon the new information gathered; and (4) to ensure that the public health is protected and to ensure impacts to the environment are minimized. The Response to Comments on EOEEA #5027 is provided in **Appendix 2**.

This Update is organized into 8 main topics. (A) Mosquito control program review; (B)Description of the mosquito control monitoring program; (C) Status of annual report of mosquito control activities and monitoring results; (D) Status of Open Marsh Water Management best management practices;(E) listing of plans, analyses, policies developed since 1998 GEIR; (F) status of coordination efforts with other state agencies; (G) Workplan and schedule for developing additional information and procedures to assess and guide SRMCB; (H) Review of peer reviewed literature on alternatives to current mosquito control practices that were suggested by Comments on the 1st GEIR update.

Synopsis.

This Update documents that the practice of mosquito control in Massachusetts adheres to the tenets of Integrated Pest Management (IPM). Practices and procedures have been further refined since the 1998 GEIR, but there have been no major changes. Monitoring, an integral component of IPM, is always undertaken for aerial applications of larvicide; is almost always performed to determine whether action is required in response to requests for service; is done on an ad hoc basis for other activities; and will be implemented more consistently under the new Best Management Practices for wetlands interventions. The most significant difference in mosquito control relative to the 1998 GEIR is the need for West Nile virus surveillance, which has placed a financial burden on mosquito control projects. Much progress has been made in developing best management practices and workplans in collaboration with stakeholders. The availability of all pertinent documents on the SRMCB website, including annual reports by each of the 9 mosquito control projects (hereafter MCP), greatly enhances public transparency and accountability. SRMCB will work with the mosquito control projects and stakeholders to incorporate any future improvements in control technologies or changes in scientific knowledge of mosquito population biology into the practices and procedures of mosquito control in Massachusetts.

Limitations and Challenges for Updating the Mosquito Control EIR

Comments on the 1998 GEIR and on the 1st Update have focused attention on questions of efficacy of current practices and procedures and whether what is undertaken in Massachusetts is consistent with the remainder of the United States. In addition, there is considerable interest among stakeholders in measuring the effect of anti-mosquito activities on the environment, including nontarget species such as aquatic macroinvertebrates, fish, amphibians, and birds. Wetlands interventions (freshwater and salt or brackish water) attract attention due to the potential invasive nature of altering drainage patterns. Data to measure the effects of anti-mosquito activities has been sought. However, resources vary between mosquito control projects. Some have funding levels that allow for the longterm stability of a diverse staff of full time employees (FTE) ; others have fewer than 5 staff members. The extent of possible activities additional to attending to the needs of the citizens who reside in the member Towns is related to FTEs and operational funds. Some mosquito control projects (those with greater resources) provided large amounts of information or data; others, much less. By necessity, the Update has been based on materials and information from the larger mosquito control projects. Comparing Massachusetts practices and procedures with others nationwide is difficult because peer reviewed summaries of "typical" mosquito control projects are not available. Publication is usually driven by research on new or unresolved questions (there is little utility in repeatedly publishing data on efficacy of any given practice or procedure), which is generally a luxury for any mosquito control project; their mission is focused on the direct task of reducing annoyance and risk of ill health. Thus, secondary sources of information such as online World Wide Web links have been invaluable in establishing what might comprise a national standard.

A. Mosquito Control Program Review

A.1. General goals of mosquito control

"Mosquito control" seeks to reduce annoyance by mosquitoes and prevent mosquito-borne infection. Because pest mosquitoes also may serve as vectors for infectious agents, reducing annoyance should be considered a public health measure. Reactive mosquito control activities are undertaken in response to citizen complaints, surveillance demonstrating increased mosquito density, or as a result of the detection of infectious agents within human biting mosquito species. Proactive activities seek to reduce the likelihood that reactive measures would be required in the future: sites are manipulated so that they become less conducive to mosquito breeding, and citizens are educated so that they do not promote mosquitoes around their homes.

A.1.A. Integrated Pest Management.

Mosquito control today uses an integrated pest management (IPM) approach (http://www.epa.gov/pesticides/health/mosquitoes/mosquitojoint.htm). The definition of IPM from the National IPM Network is the following: "IPM is a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health, and environmental risks." As defined in the National IPM Roadmap, IPM is a "long-standing, science-based, decision-making process that identifies and reduces risks from pests and pest management related strategies. It coordinates the use of pest biology, environmental information, and available technology to prevent unacceptable levels of pest damage by the most economical means, while posing the least possible risk to people, property, resources, and the environment. IPM provides an effective strategy for managing pests in all arenas from developed residential and public areas to wild lands. IPM serves as an umbrella to provide an effective, all encompassing, low-risk approach to protect resources and people from pests".

SRMCB Definition of IPM: The SRMCB definition of IPM appears to be based on that from the State Pesticide Control Act (section 7 of Chapter 132 B of the MGL):

> "Integrated pest management", a comprehensive strategy of pest control whose major objective is to achieve desired levels of pest control in an environmentally responsible manner by combining multiple pest control measures to reduce the need for reliance on chemical pesticides; more specifically, a combination of pest controls which addresses conditions that support pests and may include, but is not limited to, the use of monitoring techniques to determine immediate and ongoing need for pest control, increased sanitation, physical barrier methods, the use of natural pest enemies and a judicious use of lowest risk pesticides when necessary.

The SRMCB website [http://www.mass.gov/agr/mosquito/index.htm] comments that "IPM fosters the integration of a variety of strategies such as surveillance or monitoring for both immature and adult mosquitoes to determine and justify the need for mosquito control interventions. IPM identifies, documents, and corrects conditions conducive to development of mosquitoes (if and when feasible). IPM conducts campaigns to reduce mosquito sources as well as establish outreach efforts to educate the public on how best to reduce of sources of mosquitoes in and around their property. IPM include the use of biological control methods such open marsh water management (OMWM) to increase fish and birds on salt marsh areas. IPM also involved the judicious use of pesticides using low risk and environmentally acceptable larvicide (those pesticides that impact the immature mosquito), and, when necessary, adulticides (those pesticides that impact adult mosquitoes), to help alleviate annoyance and suppress disease threats such as West Nile virus (WNV) and Eastern Equine Encephalitis virus (EEEV)". The SRMCB definition of IPM is consistent with the general definition of IPM and that of the State Pest Control Act.

Note that the main feature of IPM is the use of complementary, multiple approaches to achieve pest control goals. Logistical and economic considerations may limit the number of approaches that could practically be used; the failure to incorporate all known measures should not imply that IPM is not being undertaken.

A.1.B. Benefits of mosquito control.

Mosquito control in the U.S. has not been subjected to a comprehensive formal cost-benefit analysis. One preliminary economic study using a Contingent Market Valuation approach (Ofiara and Allison 1986) suggests that mosquito control ranks in the same range with water quality and air quality with respect to perceived benefit as measured in dollar value per household. The 1998 GEIR recommended that research funds be made available to undertake a formal cost-benefit analysis but this has not been accomplished. Such an objective is complicated by sociological factors (some communities or socioeconomic cohorts may differ with respect to tolerating nuisance) and by difficulties in assigning monetary value to intangibles such as being able to enjoy one's own backyard. On the other hand, the public health benefits of mosquito control are better defined. Reducing risk for mosquito-transmitted infection such as West Nile virus or Eastern equine encephalitis is generally accepted as meritorious. A single case of EEE disease has been estimated to cost society $3,000,000 (Villari et al. 1995); CDC estimates that a case of West Nile disease may cost society an average of $36,000 (Zohrabian et al. 2006). Risk of WNV exposure outweighs any risk due to insecticide use (Peterson et al. 2006).

A.1.C. Basis for administrative structure of mosquito control activities in Massachusetts. The distribution and abundance of all living organisms depends on site specific factors such as microhabitat, weather, and historical contingency (to include faunal and floral associations). In Massachusetts, there are more than 50 mosquito species (8 genera) that have been documented or may be expected due to their existence in Connecticut (Andreadis et al. 2005) and of these, 21 are targeted by mosquito control activities (Table 1).[1] Each species has its own ecology; each Town in Massachusetts may have a different mosquito fauna. Accordingly, it is difficult to have a single statewide standard operating procedure (SOP) for each facet of mosquito control. Nonetheless, SRMCB has worked towards standardization when and where practical, especially for issues that affect all MCPs such as freshwater habitat management.

Table 1. Common mosquito species of Massachusetts and their characteristics

Mosquito species[2]	**human biter?**	**Degree of nuisance**	**Vector**[3]**?**	**Months of activity**	**Habitat**
Coquilletidia perturbans	Y	++++	E,Z	May-Sept	Cattail swamp
Culiseta melanura	N	--	E	May-Dec	Red maple/cedar swamp
Culex pipiens	?	+	E,Z	All year	stagnant water
Culex restuans	?	+	E,Z	All year	stagnant water
Culex salinarius	Y	+	E,Z	All year	Brackish
Anopheles punctipennis	Y	++	?	May-Sept	woodland pool
Anopheles quadrimaculatus	Y	++	?	All year	woodland pool
Aedes abserratus	Y	++++	?	May-July	sphagnum, bogs
Aedes canadensis	Y	++++	Z	May-Oct	woodland pool
Aedes cantator	Y	++++	Z	May-Oct	salt marsh
Aedes cinereus	Y	++	E,Z	May-Oct	woodland pools
Aedes excrucians	Y	++++	Z	May-Aug	woodland pools
Aedes fitchii	Y	++	?	May-June	Ditches
Aedes japonicus	Y	++++	?	June-Oct	Containers
Aedes punctor	Y	++++	?	May-June	woodland pools
Aedes sollicitans	Y	+++++	Z	June-Oct	salt marsh
Aedes stimulans	Y	+++	Z	May-Sept	woodland pools
Aedes taeniorhynchus	Y	+++++	Z	June-Oct	salt marsh
Aedes triseriatus	Y	++	E,Z	June-Oct	treehole, tires
Aedes trivitattus	Y	++	Z	June-Oct	woodland pools
Aedes vexans	Y	++++	Z	May-Oct	Floodwater
Psorophora ferox	Y	+++	Z	June-Oct	woodland pools

[1] New invasive species may be predicted for Massachusetts, e.g., the Asian tiger mosquito *Aedes albopictus*, but until they are detected concern should be limited to existing fauna.
[2] For this Update, the genus *Aedes* includes those currently classified in the genus *Ochlerotatus*
[3] Demonstrated aspects of vectorial capacity or virus (eastern equine encephalitis, West Nile virus, California encephalitis group virus) has been detected from mosquitoes sampled in New England; E=enzootic vector, Z=zoonotic vector

Although "mosquito control" comprises 5 basic operations (surveillance; source reduction; larviciding; adulticiding, education), and there are only a limited number of methods that are used for each of these operations, the actual choice of methods requires knowledge of the local condition and ultimately depends on available resources or constraints of local politics. For example, although the basic life cycle of the house mosquito, *Culex pipiens*, is the same regardless of whether it is from Boston or Framingham, house mosquito density might vary as a function of the availability of clogged house gutter developmental habitats, in which case the latter city would be more favorable; or as a function of pigeon roosts (bloodmeal source), in which case the former would be more favorable. Intervention to reduce the density of *C. pipiens* (the main enzootic[4] vector of West Nile virus) would differ depending on the city: spraying to kill adult mosquitoes or applying larvicides to urban developmental habitats (catch basins) would be less effective or require more investment of resources in Boston; spraying would be more effective in Framingham but larviciding not practical for clogged house gutters. Thus, mosquito control projects should be locally developed and sustained. Florida, for example, has more than 50 separate mosquito control districts reflecting the diversity of habitats and community standards there. It is possible that an inflexible, statewide action threshold and standard operating procedure might actually greatly increase pesticide use: current practice emphasizes locally targeted, experienced-influenced, preemptive methods whenever possible but waiting for a threshold to be attained increases the likelihood of needing area-wide reactive application such as aerial ultralow volume spraying (ULV).

Chapter 252 of the Massachusetts General Laws (MGL) created the State Reclamation and Mosquito Control Board (SRMCB) which oversees mosquito control in the Commonwealth including creating local mosquito control projects. The SRMCB is comprised of one representative each from the Department of Environmental Protection (DEP), the Department of Agricultural Resources (DAR) and the Department of Conservation and Recreation (DCR). The SRMCB appoints Commissioners to carry out improvements in the 9 mosquito control projects (MCP) in Massachusetts, which are: Berkshire County, Bristol County, Cape Cod, Central Massachusetts, East Middlesex County, Norfolk County, Plymouth County, Suffolk County, and the Northeast Massachusetts Mosquito Control and Wetlands Management District (formerly Essex County MCP). Commissioners comprise diverse occupations ranging from mayors to health agents to biologists and represent the various towns within each project. Commissioners exercise general oversight of the project locally and employ the MCP Superintendent who manages the day-to-day work.

The origins of the current structure for mosquito control in Massachusetts are discussed in the 1998 GEIR; much of the impetus for the formal establishment of mosquito control in the Cape Cod and Northeast regions related to the detrimental effect of mosquito nuisance on coastal tourism and development. For Bristol and Plymouth Counties, the threat of EEEV transmission in the 1950s stimulated the formation of their respective MCPs. MCPs thus exist to reduce annoyance by mosquitoes and to reduce public health risk related to mosquito-transmitted infections (due to arboviruses such as EEEV and WNV). The two reasons are interrelated inasmuch as the density of mosquitoes with broad host range ("bridge vectors", whose hosts

[4] Enzootic" refers to the natural cycle and does not imply any impact on human health. "Epizootic" refers to an intensification of the enzootic cycle. "Zoonotic" specifically refers to human risk, particularly the capacity of an animal infection to cause disease in people.

include humans as well as other animals), which comprise those species that cause annoyance, also influence the probability of the development of transmission thresholds for viral epizootics. Thus, annoyance reduction should be considered a public health action.

A.1.D. Current MCP membership of Massachusetts towns

Of the 351 Towns in Massachusetts, 193 (or 54.9%) belonged to the 9 organized mosquito control projects during 2008, a 23% increase in participation since 1998 (157 towns). The median number of towns participating per MCP is 25, with an interquartile range of 15-28. Resources (budgets and full time employees, FTE) vary greatly. There has been no change since the 1998 GEIR in the mode of funding MCPs and the detailed mechanism for each is provided there. In brief, the MCP budget is provided by the State and administered by SRMCB. Funds are paid to the State by participating Towns based upon taxable valuations (5-20 cents per thousand dollars of taxable valuations), with the exception of East Middlesex MCP, which receives voluntary appropriations from participating cities and towns. The precarious nature of this funding mechanism is underappreciated: a Town may withdraw from participation at any time by Town Meeting vote. The loss of even one Town for the average MCP could translate to the loss of an FTE. In addition, because the funds come from Towns, budget increases that might allow additional activities or services are unlikely to materialize, particularly given the current economy.

A.1.E. Overview of Mosquito Control Projects:

Table 1 provides a brief overview of each MCP. The number of full time employees (FTE), 2008 budget, number of participating Towns (2008), extent of IPM activities undertaken, and number of mosquito species needing attention in their jurisdiction is outlined. Four MCPs (Bristol, Norfolk, Northeast, and Plymouth) offer the full range of IPM services. Cape Cod does not adulticide. East Middlesex and Berkshire do not engage in source reduction. All participate in surveillance, which comprises sampling (usually in longterm trapsites) adult mosquitoes and sending them to the Massachusettts Department of Public Health's State Laboratory Institute for EEE/WNV testing. Overall, MCPs appear to embrace the full range of activities that comprise integrated pest management.

Table 2. Characteristics of Massachusetts Mosquito Control Districts. Information from the 2008 Annual Reports.

		2008			**#**
MCP	**FTE**	**budget**	**#towns**	**IPM**	**mosquito spp**
Berkshire	2	154,533	8	L,A,D,AS,E	9
Bristol	9	1,089,627	20	L,A,S,D,O,AS,E,R	14
Cape	23	1,538,669	15	L,S,D,AS,E,R	12
Central	18	1,473,888	39	L,A,S,D,AS,E,R	15
E. Middlesex	5	569,751	25	L,A,S,D,AS,E,R	20
Norfolk	11	1,467,822	25	L,A,S,D,O,AS,E,R	18
Northeast	9	1,429,559	32	L,A,S,D,O,AS,E,R	14
Plymouth	11	1,429,559	28	L,A,S,D,O,AS,E,R	22
Suffolk	2	234,637	2	L,A,S,D,AS,E,R	10
Median	9	1,429,559	25		14

IPM key: L, larviciding; A, adulticiding; S, source reduction; D, ditch maintenance; O, open marsh water management; AS, adult surveillance; E, education and outreach; R, research

A.1.F. Practices and procedures used by MCPs: changes since 1998 GEIR.

Current MCP activities are essentially unchanged since the comprehensive 1998 GEIR, with the exception of more of a focus on surveillance and management of West Nile virus vectors. West Nile virus (WNV) emerged in 1999 in New York City and subsequently spread to all of the contiguous 48 states within 5 years; it is now the most common cause of morbidity and mortality[5] associated with bloodfeeding arthropods in the U.S. (Kramer et al. 2007; Telford and Ebel 2008) Ground and aerial based ultralow volume spraying, larviciding, source reduction, education, and wetlands management practices and procedures remain the same. Active ingredients, for example, the main use of *Bacillus thuringiensis israelensis* (Bti) for larviciding, also remain very similar. However, proactive sampling of adult mosquitoes and in particular *C. pipiens* has required MCPs to integrate expertise in mosquito identification for sorting light trap catches; use specialized sampling devices (gravid traps for ovipositing *C. pipiens*); and target important *C. pipiens* developmental habitats (catch basins). More emphasis is now placed on public education. Best Management Practices have been or are being developed for wetlands management. Geographic information systems (GIS), global positioning system (GPS) and computer controlled flowmeter technology has been developed and adopted to allow for greater precision in pesticide application and recording application data. Annual reports from each MCP and pertinent documents related to mosquito control are now freely available on the SRMCB website.

Chemical control (larviciding and adulticiding) and source reduction, including open marsh water management, continue to dominate mosquito control in Massachusetts and has not significantly changed in scope or practice since the 1998 GEIR. Aerial applications of larvicides are used by several MCPs mainly to preempt the emergence of snow melt (spring breeding) mosquitoes. Public education is, in contrast to a decade ago, an important component of most MCPs. These practices and procedures are consistent with other current state mosquito control programs (http://www-rci.rutgers.edu/~insects/bmpmcnj.pdf; http://www.cdph.ca.gov/HealthInfo/discond/Documents/CDPHBMPMosquitoControl6_08.pdf[6])

A.1.G. Influence of West Nile virus

All MCPs sample host seeking and gravid mosquitoes and have them tested according to established pool limits at the Massachusetts Department of Public Health's State Laboratory Institute (hereafter MADPH) for evidence of infection by WNV and EEE. When evidence of enzootic viral transmission is detected in human biting mosquito species, intensified intervention is undertaken. In response to confirmation of viral activity in any pool of human-biting mosquitoes, MCPs will consult with local and state officials, as well as established protocols in the State Arbovirus Surveillance and Response and SRMCB Operational Plan (Documents 2 and 3 in Section E) and give a recommendation regarding the appropriate response. MCPs may immediately adulticide the site where positive mosquitoes were trapped, as well as the surrounding neighborhoods as a response to the viral confirmation. Other responses may include

[5] Although Lyme disease is the most common vector-borne infection in the U.S., it is not a significant cause of mortality. The case fatality rate for WNV disease (those who become sick after being infected; the majority of infections, though, do not cause illness) is 7%.

[6] URLs are provided because relevant published documents are not available. In addition, URLs with direct links allow readers to instantly examine documentation. Note that URLs may change over time.

all or some of the following: increased larval control, public education, and community outreach using various media outlets.

Focusing preemptive efforts (larviciding or source reduction) on known enzootic vector species is controversial: the cryptic nature of *Culiseta melanura* (within pools of water under red maple/white cedar swamp root systems) or *Coquilletidia perturbans* (within the roots of cattails) larval development render these mosquitoes virtually impossible to economically target. The quantitative relationships between enzootic vector breeding and adult stages, bird populations, seasonal dynamics, enzootic (bird cycle) transmission, and human EEE risk are not completely understood (Hachiya et al. 2007). Similarly, although *Culex pipiens* and *C. restuans* are critical enzootic vectors, the actual human biting species that pose risk for human WNV infection ("bridge vector") remains a focus of research. In fact, older *C. pipiens*, typically a species highly restricted to birds, will feed on people and it may be that this mosquito is the main WNV zoonotic vector (Hamer et al. 2008). For EEEV, a series of action thresholds have been adopted to guide intervention responses to the repeated detection of this virus in human-biting mosquitoes and the reader is referred to the MADPH Arbovirus Surveillance and Response Plan (as listed in Section E and available online at http://www.mass.gov/agr/mosquito/mepa_filing_102408.htm).

WNV-related activities have placed an extra burden on the economics of mosquito control in Massachusetts since the 1998 GEIR. There is currently an emphasis by MCPs on the preemptive suppression of *C. pipiens* by attention to catch basins, gutters, abandoned swimming pools, and other repositories of the filthy water preferred by this mosquito for oviposition. In addition, surveillance efforts assisting MA DPH require the use of gravid or oviposition traps (as opposed to CDC light traps, which capture host-seeking mosquitoes), which were rarely used in the past; WNV activity is most efficiently detected by sampling gravid *C. pipiens*[7]. Central MCP estimates an extra $100,000 (one fulltime entomologist to sort mosquitoes for viral testing, in addition to seasonal employees to tend light traps and gravid traps as well as treat catch basins; plus additional supplies and equipment) is now required each year to accomplish activities related to WNV surveillance and control. Cape Cod MCP estimates an extra $60,000 is required for similar activities related to WNV surveillance and control. As an example of how labor intensive WNV preemption may be, Plymouth MCP applied larvicide to 59,047 catch basins in their member Towns during 2008.

Due to budgetary restrictions, MA DPH was able to only assume the costs for testing no more than 40 pools of mosquitoes per MCP per week during 2008. Additional pools (required due to the number of communities monitored by certain MCPs) needed to be funded at $25 per pool by an individual MCP, resulting in an extra burden of as much as $400/week for the 2 months (August-September) of WNV transmission potential. During 2009, with difficult State budgets, MA DPH may not be able to support any of the testing costs. For larger MCPs such as Central, this may translate to allocating more than $20,000 each year to continue a service that member Towns tend to view as essential. Detection of virus (EEE or WNV) in any mosquito pool from any Town would prompt intensified surveillance, and any additional positive pools would trigger

[7] Gravid mosquitoes have taken a bloodmeal and therefore have the potential to be infected. Nongravid mosquitoes may be nulliparous (never laid eggs) or parous (fed and therefore ready to lay eggs or have already done so). Light traps will sample both nulliparous and parous mosquitoes.

thorough ground based ULV adulticiding.

A.1.H. Larviciding and adulticiding

Salt marsh mosquitoes (*Aedes taeniorhynchus* and *A. sollicitans*) remain the primary target of coastal MCPs (Cape Cod, Northeast, Norfolk, Plymouth, Bristol) whereas inland programs target springbrood and summer-reflood *Aedes* spp. In both of these situations (coastal and inland), attempts are made whenever possible to reduce annoyance by larviciding. Not all developmental habitat is accessible[8] or historically identified to allow proactive larviciding. In addition, citizen complaints about biting mosquitoes must target adult mosquitoes. Thus, adulticiding complements larviciding for reducing annoyance.

The classes of chemicals used for mosquito control in Massachusetts and their mode of application have not significantly changed since the 1998 GEIR. MCPs have continued to use the lowest risk agents available for environmental and occupational health reasons. The chemicals that are currently being used are not appreciably different from those used in other states, as suggested by available information from California(http://www.cdph.ca.gov/HealthInfo/discond/Documents/CDPHBMPMosquitoControl6_08.pdf), New Jersey (http://www-rci.rutgers.edu/~insects/bmpmcnj.htm), and Maryland (http://www.mda.state.md.us/plants-pests/mosquito_control/insecticides_for_mosquito_control_md.php) as national examples. As with pharmaceuticals in health care delivery, choice of specific brands and active ingredients may be influenced by several factors, including continuing education at regional or national mosquito control association meetings; publications in trade or scientific journals; targeted sales promotion by the major mosquito control products companies; and economic or procedural considerations by MCPs. Interestingly, although budget considerations are important to all MCPs, the least expensive effective adulticide, malathion, is rarely used in Massachusetts (although it is legal to use) because of the IPM tenet of using the lowest impact pesticide whenever possible.[9]

A.1.H.1. Larviciding. Larviciding involves the application of pesticides or biological agents in water where mosquitoes might breed. Proper larviciding must consider many factors including delivery of the control agent, method of application, effective duration of treatment, and toxicity to non-target species. Larviciding generally relies on microbial insecticides. The most common microbial insecticides include the bacteria *Bacillus thuringensis serovariety israelensis* (Bti) and *Bacillus sphaericus* (Bs). Applications involving these two bacteria are the predominant non-chemical approach to mosquito control in the United States, with their use expanding greatly during the past 20 years (Lacey 2007). Bti's (and Bs) mode of action is by a toxin produced by the bacteria that when ingested by the larvae leads to their death within 24 to 48 hours. The toxin is rendered active only in alkaline conditions, a feature unique to the intestinal tract of mosquito and blackfly larvae. The requirement for an alkaline environment in which the toxin is active imparts great specificity to Bti, with the only known nontarget species comprising chironomid midges (Lacey 2007). Bti has a high degree of specificity for

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[8] An important pest species, *Coquillettidia perturbans*, is restricted to breeding in cattail marshes; indeed, the larvae inhabit the cattail root system. *C perturbans* populations can become extremely dense and often there is no choice but to rely upon adulticiding for reducing annoyance.

[9] "Lowest impact" could also include public perception or acceptance issues.

mosquitoes and blackflies and is therefore relatively safe for most non-targets including invertebrates and vertebrates. Bti can be formulated in a variety of ways including as aqueous suspensions, granular and solid forms. Formulations of water dispersible granules (WDG) can be used in ultra low volume (ULV) spray equipment. Solid formulations are used for "container" application (e.g., used tires). Documentation of longterm effects of Bti use is sparse; there is a suggestion that depleting an aquatic environment of blackfly larvae might impact the population density and species richness of macroinvertebrate predators that rely on such prey (http://wnv.wsu.edu/referencematerial/pdf/microbial mosquito control.pdf).

Five of the MCPs undertake a March or April aerial application of Bti by helicopter, targeting mainly spring floodwater/snowmelt mosquito species (*A. abserratus*, *A. excrucians*; secondarily, *A. canadensis*, a prominent summer species that breeds in the same sites), which can explosively emerge; these are important nuisance species and may be responsible for a large fraction of service calls. Such applications are reserved for sites >5 acres that historically have yielded evidence of serving as a source of springbrood/snowmelt mosquitoes. Pre-treatment data is collected and "recoverable dip stations" (RDS), each comprising 10 dip sites, established within and outside the treatment zones. GIS mapping (ArcView swath guidance system) used by the principal helicopter contractor for the MCPs has produced relatively precise coverage of targeted areas. The treatment threshold used by Central Mass MCP is an average of 1 larva per dip over the RDS. Vectobac G is applied at 5 lbs/acre by a helicopter contractor who is provided with GIS maps delineating treatment zones. For the 2007 Central Mass MCP application in the towns of Billerica, Chelmsford, and Boxborough, average efficacy 48 hours after application was 87% reduction of larvae whereas in RDS outside of treatment zones an average of 22% increase was documented. Data on the efficacy of recent aerial applications of larvicide are provided for Central Mass, Norfolk, Plymouth, and E. Middlesex MCPs in **Appendix 3**.

Altosid (methoprene) is an insect growth regulator (IGR) which disrupts larval development. It is used in slow release formulations to provide larval control for up to one month in relatively static standing water applications such as catch basins. Altosid (as well as two pyrethroid adulticides) has been the subject of controversy with respect to its intensive use in catch basins to suppress WNV in the New York city area when this virus first emerged in the U.S., particularly with the commercial lobster industry claiming that runoff from catch basins into Long Island sound influenced the survival of maturing lobsters. Critical examination of the issue failed to support such claims (Zulkowsky et al. 2005). Indeed, methoprene has excellent safety characteristics including its low risk to mammals and birds as well as failing to accumulate in the environment (http://pmep.cce.cornell.edu/profiles/extoxnet/haloxyfop-methylparathion/methoprene-ext.html). An in depth review of methoprene has been conducted in New Zealand (http://www.moh.govt.nz/moh.nsf/0/FF3B628D67E34963CC256BA3000D8476/$File/s-methoprene.pdf) to determine whether its use should be permitted there; this report concluded "Methoprene has longer persistence than Bti after application, but also causes greater impact on non-target organisms. Despite this, there is no indication in the literature of permanent disruption to ecosystems after methoprene application." Although some suggestion has been made that methoprene may contribute to frog limb deformities, the hypothesis that is currently best supported by data is that aquatic eutrophication due to agricultural nutrient runoff renders frogs more likely to be infected by a trematode parasite (Johnson et al. 2007) which may serve as a teratogen.

All current larvicides used in Massachusetts (Table 3) with the exception of Agnique are EPA toxicity category[10] IV (1 pint or pound ingestion for lethal human dose) and all current adulticides are category III (1 ounce to 1 pint lethal dose). Malathion is no longer listed as available at any MCP; interestingly, CA, NJ, MD, and NY all continue to list malathion as useful, demonstrating that Massachusetts MCPs have carefully considered the IPM tenet of using only the lowest risk active ingredients even if these are more expensive. Indeed, abate only costs $0.19/acre but Bti $8.50/acre yet all MCPs consider Bti to be their most effective tool. There is only one organophosphate compound (Abate) that might occasionally be used in Massachusetts; Northeast was the only MCP that reported any use of Abate (50 oz of 5% abate, total) during 2008.

Late stage (4th instar) larvae and pupae, which ingest little or nothing and thus would not be targeted by Bti or Bs or are not susceptible to methoprene, are targeted by monomolecular films of mineral oil on the surface of water of developmental habitats to prevent their air tubes from working.

Table 3. Agents currently used for larviciding in Massachusetts. Product labels and MSDS for each are provided in Appendix 4.

Trade name	**Chemical name**	**EPA registration number**
Vectobac G	*Bacillus thuringiensis israelensis*	73049-10
Vectobac 12AS		275-012
Vectolex WSP	*B. sphaericus*	73049-20
Vectolex WDG		73049-57
Vectomax CG	Bti + *B. sphaericus*	73049-429
Summit	Bti	6218-47
Altosid WSP	Methoprene	2724-448
Altosid XR		2724-421
Aquabac XT	Bti	62637-1
Aquabac G		62637-3
Agnique MMF	isooctadecanol	53263-28
GB1111	mineral oil	8898-16
Teknar G	Bti	70051-73
Skeeter Abate	temephos	8329-15

A.1.H.2. Adulticiding. All of the active ingredients[11] for adulticiding, and indeed many of the actual products (Table 4), were listed in the 1998 GEIR. The largest change since 1998 has been a shift from the use of Scourge and Flit to Suspend and Anvil for adulticiding. Anvil tends

[10] EPA classifies chemicals in a range from "practically nontoxic" to "highly toxic" (http://www.fs.fed.us/r6/invasiveplant-eis/Region-6-Inv-Plant-Toolbox/Herbicide%20Info/EPA-Toxicity-Categories-081607ver.pdf)
[11] Active ingredient (AI) = chemical name

to be the product of choice given its extensive review by stakeholders during and after the 2006 aerial intervention against EEE (MEPA Document 11, "Choice of Anvil 10+10, http://www.mass.gov/agr/mosquito/docs/mepa/Document_11_Choice of Anvil 10+10 for Aerial Mosq Cont Memo .pdf). Scourge and Flit use has been discouraged due to SRMCB policy regarding the Children's Protection Act. Pursuant to MGL c132B, Section 6G, of the Massachusetts Pesticide Control Act, pesticide products containing chemicals classified as known, likely, or probable human carcinogens by the U.S. EPA or equivalently categorized by the Department of Agricultural Resources, are not eligible for use outdoors on the facility grounds of any school, day care center or school age childcare program. Permethrin and resmethrin are currently classified by the EPA as known, likely or probable carcinogens (http://massnrc.org/ipm/schools-daycare/ipm-tools-resources/school-property-chemicals.html). Because these active ingredients cannot be used on school grounds, their use on nearby properties seems inconsistent with the spirit of MGL c132B, Section 6G.

Table 4. Chemicals currently used for adulticiding in Massachusetts. Product labels and MSDS for each is provided in Appendix 4.

Trade name		Chemical name	EPA registration number	
Anvil 10+10		Sumithrin*		1021-1688-8329
Suspend SC		Deltamethrin		432-763
Scourge 18+54		Resmethrin*		432-667
Flit 10EC		Permethrin		8329-67

*, synergized with piperonyl butoxide

Ultralow volume (ULV) spraying continues to be the main mode of delivery for adulticides by MCPs. ULV is defined as the delivery of less than 5 liters per hectare of pesticide using precisely engineered nozzles that ensure that droplet size is exceedingly small, <100 microns in diameter, and more typically, 10-20um. The total amount of active ingredient for a typical ground ULV application of Anvil can be 0.2-0.3 ounces (5 milliliters/1 teaspoon) per acre. All MCPs use pickup-truck mounted as well as portable handheld ULV sprayers for adulticiding. Barrier applications of Suspend are applied at a rate of 1 gallon/minute using a truck-mounted sprayer, not necessarily ULV. Barrier treatments applied by mist-blower are not commonly used by MCPs although they tend to provide more longterm (2 week) suppression due to residual action of the adulticide[12]. Backpack sprayers are used to apply liquid larvicides and, in some instances, adulticides (e.g., where trucks cannot adequately broadcast by ULV spraying such as in backyards or for selective treatment of one house among many[13]). Granular materials (Bti) are

[12] Barrier applications of residual insecticide provide protection for a greater amount of time, 2 weeks or more, thereby reducing the need for repeated ULV treatments of sites where there is great human activity at dusk, e.g., parks and playing fields. On the other hand, nontarget impact might be greater due to the active ingredient persisting longer in the environment than does ULV-applied chemical; but, peer reviewed evidence of such nontarget effects is not available.

[13] Note that backyard spraying of adulticide is limited by EPA registration (label) to after sunset and before dawn hours to minimize effects on nontarget species such as honeybees. Thus, relatively little of such targeted, yard specific intervention is done due to the possibility of staff injury while walking in the dark.

applied by hand or with cyclone-type spreaders. Briquet formulations (Bti or methoprene) are applied by hand. Area-wide truck mounted aerosol spraying is undertaken using protocols that provide the most efficient control, such as identifying neighborhoods with dense configuration of streets; scheduling sprays when minimum temperatures exceed 60ºF in which mosquitoes are more active; and in periods around dusk when the greatest mosquito host-seeking occurs.

Figure 1. Sample printout from ULV application report.

```
                                                  Elec 2 368H.txt
DC3 Report: Elec 2 368H.txt

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Statistic Summary
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Mass Median Diameter (microns): 18.3514
Sauter Mean Diameter (microns): 8.0363
Volume Mean Diameter (microns): 3.4136
Area Mean Diameter (microns): 2.2249
Number Mean Diameter (microns): 1.6617
VmeD 90% (microns): 25.5968
VmeD 10% (microns): 2.7171
VmeD Span 90% - 10% (microns): 1.2468
Number Median Diameter (microns): 1.5231
NMD over VMD (microns): 0.0830
Droplets over 32 microns: 0
Droplets over 48 microns: 0
Total Count: 1000
Droplet Type: Oil
Collection Time: 19

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Environment
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Collected By: T.W.
Comments:
Humidity:
Test Number: 10
DateTime: Wed Jul 02 10:25:11 2008
CustomerName: C.M.M.C.P
DistanceToNozzle: 24 in
Flow: .24 oz/acre
SprayerType: Pro Mist 25HD
SprayerID: Elec 2
AmbientTemperature: 73
ProductTemperature:
Product: Anvil 10+10
Pressure:
WindSpeed: 1.2 ave
Weather: mostly cloudy
Rpm:
Formulation:
Diluent:
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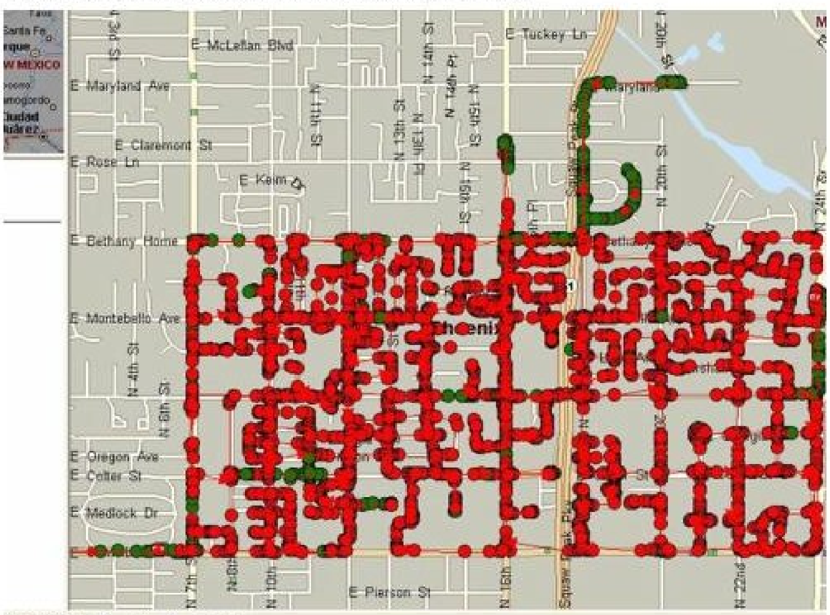
Technology is increasingly precise. Most ULV trucks contain global positioning system (GPS) units that provide detailed maps of spray sites, including the location of "no spray" households. Computerized systems track and record the amount of active ingredient used, time of application, windspeed and temperature and such detailed records are kept as evidence of application (Figure 1). In fact, because of this precision delivery, in the aftermath of the terrorism of 9-11 (2001), ULV machinery was disabled and locked down until security policies were developed to prevent their theft and use for delivery of chemical or biological weapons. All MCPs currently have enhanced security policies for their materials.

Figure 2. Example of a Datamaster output documenting an actual adulticiding run within an urban environment.



New interfaces such as the Datamaster (Clarke Mosquito Products) can record the exact route of application along with details of the application (Figure 2). Although only Norfolk and E. Middlesex MCPs currently use this instrument, this is a tool that all would find useful and is likely to be adopted in the near future if budgets allow.

The efficacy of adulticiding using ULV was critically examined by a MADPH Working Group (May 25, 2006) with the development of an annotated bibliography; this report is provided in **Appendix 5**. Aerial ULV has been extensively reviewed in the context of EEE intervention (see Section E for a list of analyses submitted for the 1st GEIR update). Aerial anti-WNV adulticiding has been demonstrated elsewhere to reduce risk of acquiring WNV (Carney et al. 2008). In contrast, the efficacy of ground-based ULV intervention against WNV remains to be determined but may be greatly dependent on local factors (Lothrop et al. 2008; Reddy et al. 2006). Measuring the efficacy of ground based or aerial ULV for standard adulticiding is complex. Most published studies have used caged mosquitoes, which does not simulate conditions in nature. Not all mosquitoes in a site at the time of an application may be seeking hosts; resting mosquitoes within vegetation may be less likely to encounter an insecticide droplet. In addition, new adult mosquitoes may be constantly emerging. It is possible that a post-treatment count of adult mosquitoes 24-48 hours after adulticiding may not demonstrate a diminution in density; a nearby non-treated control site would also have to be monitored to exclude the possibility that a local process other than adulticide influenced the counts.

A.1.I. Potential products for future use in larviciding or adulticiding

All products used for mosquito control (adulticiding or larviciding) must be reviewed by EPA under the Federal Insecticide Fungicide and Rodenticide Act (FIFRA), and labelled with specific indications and precautions. Indeed, "the label is the law" (http://www.epa.gov/opp00001/regulating/labels/label_review.htm), meaning that the product must be used as directed by the label; any other use is unlawful. In addition, for use in Massachusetts, new pesticides must be reviewed and registered by the Massachusetts Pesticide Board Subcommittee of the Department of Agricultural Resources' Division of Crop and Pest Services (http://www.mass.gov/agr/pesticides/registration/index.htm). The Massachusetts registration status of any pesticide may be found at http://www.kellysolutions.com/ma/pesticideindex.htm After such registration, SRMCB provides guidance to MCPs via policy statements that may specify restrictions for use additional to those on the product label.

A new combination adulticide, Duet[14], has been available from Clarke Mosquito Control Products since 2007, appears to have a current registration the Division of Crop and Pest Services for mosquito control, but has not yet been used in Massachusetts. Duet combines an advanced synthetic pyrethroid (prallethrin) with sumithrin. Duet's advantages are that it retains efficacy in temperatures that are contraindicated for Anvil; and, the combination of active ingredients apparently stimulates benign agitation, causing mosquitoes to actively host-seek and thereby exposing more mosquitoes to ULV droplets (http://esa.confex.com/esa/2008/techprogram/paper_35011.htm), although the final results of studies have not yet been published. Because (as labeled) Anvil cannot be used at temperatures lower than 50ºF, cold tolerant species such as *A. japonicus*, which might seek hosts when other mosquitoes do not, could be targeted by Duet.

Another potential adulticide that may be useful in the near future is etofenprox, a non-ester pyrethroid (Zenivex, available from Adapco). Etofenprox appears to be effective without the need for a piperonyl butoxide (PBO) synergist and thus could be used where residents or

[14] Product labels and MSDS for Duet, Zenivex, and Spinosad are provided in **Appendix 4**.

stakeholders have expressed concerns about this chemical[15]. Etofenprox has rapid knockdown of mosquitoes; is effective against mosquitoes with organophosphate resistance; and is classified as EPA Category 4, the lowest risk to humans. It is also considered nontoxic to birds. Zenivex residues on foliage are said to be less toxic for honeybees. However, ecotoxicity studies are still pending (http://www.regulations.gov/search/Regs/home.html#documentDetail?D=EPA-HQ-OPP-2007-0804-0002) and thus chronic effects on plants or animals other than mammals are not known. Etofenprox is highly toxic to freshwater fish. Zenivex has a current Massachusetts registration for mosquito control but MCPs have not indicated that it is being used.

One promising new larvicide, Spinosad (Natular, Clarke Mosquito Inc), is a new class of insecticides derived from fermentation products of an actinomycete bacterium (*Saccharopolyspora spinosum*). When ingested, the active ingredient induces rapid excitation of the insect nervous system. Natular meets USDA National Organic Program requirements, providing the possibility for larviciding near organic farms (if required or requested). Spinosad has very low acute or chronic mammalian toxicity. However, it does have significant toxicity to oysters and other marine molluscs (http://www.nysaes.cornell.edu/pp/resourceguide/mfs/13spinosad.php) and thus would need to be used with care in salt marsh or other applications where the active ingredient might be deposited in estuarine sites by runoff. In addition, it is highly toxic to honeybees, although larvicidal formulations would not be deliberately applied to foliage. Spinosad has been used for nearly a decade for agricultural applications and has a current Massachusetts registration for residential application, but review has not been finished for mosquito control applications. Preliminary studies with mosquitoes suggest excellent efficacy in killing larvae in retention and detention ponds.

A.1.J.. Source reduction

Source reduction involves practices that reduce or eliminate potential developmental habitats of mosquitoes. Because different mosquito species breed in different habitats, source reduction practices can vary greatly. Source reduction may be as simple as emptying containers of water around a residence to large-scale water management programs in wetlands and salt marshes (Carlson 2006; Dale and Knight 2008). Around homes, developmental habitats may comprise empty cans, kiddie pools, or clogged house gutters. Discarded tires in the woods are ideal sites for the breeding of the invasive Asian mosquito *Aedes japonicus* as well as the native *A. triseriatus.* Retention and detention ponds for controlling runoff are important man-made venues for mosquito breeding (http://www.buckinghampa.org/inc/documents/8/Mosquitos-Basins.pdf). One by-product of the recent economic woes relates to the abandonment of homes due to foreclosure: swimming pools retain water that does not get cleaned and thereby serves as a large developmental habitat, similar to what was seen after Hurricane Katrina in New Orleans (Reisen et al. 2008; Caillouet et al. 2008). MCPs now work with city inspectional services to identify such homes and proactively engage in source reduction. Halifax, Massachusettts enacted in 2008 a standing water ordinance partly in response to abandoned foreclosed property and its potential role in providing developmental habitat for West Nile virus vectors (http://www.boston.com/news/local/articles/2008/07/24/a_ban_on_still_waters/). Other Towns

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[15] PBO has been suggested to be a skin sensitizer and contributor to ill health in individuals with chemical sensitivity and thus its presence in adulticides has attracted some concern. A recent review demonstrates such effects are rare (Osimitz et al. 2009).

should be encouraged to increase their tracking and monitoring of foreclosed or abandoned properties, perhaps by educational efforts targeting local Boards of Health.

Sites targeted for longterm source reduction (wetlands restoration, clearing of ditches, draining or reducing stagnant water) are selected on the basis of known larval developmental habitat (from surveillance, history of service call requests, or field personnel observation); by resident request; or by request from a Town official (Board of Health or Department of Public Works). Site history, breeding potential and a site plan survey are undertaken before deciding to embark on any intervention.

A.1.K. Paradigm for GIS use in mosquito control activities

Geographic information systems (GIS) provide powerful tools to map and interactively relate information to maps and other physical representations of habitat. Of the 9 MCPs, 8 use GIS systems; 2 of the 8 classify themselves as having advanced expertise, 4 as intermediate expertise, and 2 as beginners. The availability of GIS expertise among MCP FTEs enhances efforts to identify and remediate longterm sources of mosquitoes as well as provide a means to interact with stakeholders such as MassWildlife.

Mosquito control activities will be greatly enhanced as staff become more experienced with GIS applications. A longterm goal would be for all MCPs to use GIS for providing even more targeted applications and for documenting interventions. Resources are currently lacking in most MCPs to develop full scale GIS programs but the power of these tools will force the trend.

Table 6. Shapefiles used by Norfolk MCP GIS program.

STATEWIDE
Aerial photographs
DEP Wetland Delineation
Ponds and streams
Contours
Areas of Critical Environmental Concern

NHESP
Turtle Habitats
Certified Vernal Pools
Potential Vernal Pools
Priority Habitats of Rare Species
Estimated Habitats of Rare Wildlife

PWS
Wellhead Protection Areas
(Zone 2 and Interim Wellhead Protection Areas)
Surface Water Supply Protection Areas (Zones A, B, C)
Outstanding Resource Waters

LOCAL (Towns with advanced GIS capacity)

- Specific locations of culverts/pipes
- Channels, drains
- Water mains
- Sewer lines, catch basins
- Detailed contours (to 1-foot intervals)

Norfolk MCP, an advanced GIS user, provided a summary of their use of this technology for planning, implementation, completion, monitoring and maintenance of all its Wetland Management Activities. Many of the shapefiles available through the Massachusetts GIS website are used (Table 6), as well as any available town specific data. These data layers provide valuable information on the sites and help to ensure compliance with applicable regulations. Aerial photography and wetland delineation data layers, Natural Heritage and Endangered Species Program (NHESP) shapefiles and Public Water Supply (PWS) shapefiles are particularly important to use in wetlands management project development and compliance. For example, by visually inspecting the boundaries of these layers on an aerial photo, site boundaries can be accurately planned.

Norfolk MCP has also developed its own

shapefiles as a means of documenting all of its wetlands management activities such as standard hand maintenance, intensive brush cutting/ hand clearing, and excavation work. The attribute tables have been developed to provide as much information as possible regarding such activities. Excavation shapefiles display the exact location of the project and include information such as the address, who requested the work, name of the project coordinator, completion date, maintenance dates, a list of any associated documents, and any additional comments relative to the project. PDF files can be created showing this information and can be shared with our local towns and residents.

Hand clean[16] activity shapefiles are set up in a similar way to excavation data. The location of the hand clean is shown on the map, and relevant information included in the attribute table. Information includes location address, date completed, length cleaned and checked, date of any excavation work, its status (standard vs. intensive hand clean/ brush cutting), and any other relevant comments. These layers have been color-coded by date completed in order to ensure that regular maintenance is undertaken. As with excavation data, this information can be provided to residents and towns at their request.

A.1.L. Open Marsh Water Management (OMWM)

(See Section D, below for the status of best management practices for OMWM; also refer to the working document "10 year review of OMWM" provided in **Appendix 10**. Because the OMWM BMP is currently under discussion by stakeholders and will include a summary of practices and procedures in the final version, only a brief overview is provided here.)

"Ditching" salt marshes is one of the oldest source reduction practices of mosquito control programs in the Northeastern U.S.: small ditches are opened to larger areas allowing the influx of larvivorous fish as well as flushing by the tides, which prevents water from remaining still long enough for the full larval developmental cycle to be completed. When ditches failed to be maintained, more developmental habitats were created (Portnoy 1984). Parallel grid ditching effectively drained marshes and is now rarely used for source reduction. More recently, open marsh water management has been emphasized, with the creation of small, shallow ponds and inter-connecting ditches to reduce breeding areas with wet-dry-wet cycles. OMWM appears to be effective in reducing mosquito developmental habitat and is compatible with wetlands restoration, wildlife habitat enhancement, and invasive species abatement (Rochlin et al. 2009) . Of particular importance is that the newly created permanent water habitats formed by OMWM ponds and ditches are poor sites for mosquito egg deposition, and improve access for mosquito-eating larvivorous fishes (mummichogs, *Fundulus heteroclitus*).

A.1.M. Education and outreach. A significant change since the 1998 GEIR is the great extent of comprehensive educational programs integrated into the standard operating procedures of the MCPs. Such education comprises basic mosquito biology, description of mosquito habitat, control techniques and efforts citizens can undertake to reduce the potential for mosquito populations in their own neighborhood. An informative coloring and activity book, "The Life and Times of Miss Keeto" by Tim Deschamps and Curtis Best of Central Mass MCP is distributed to elementary schools (**Appendix 6**) in their member Towns. News releases on surveillance results are provided to local press. Library displays are produced. Presentations are

[16] Removal of water flow obstructions or vegetation by hand or rake.

made to elementary school through high school students as well as to health fairs. In 2008, 2,952 students and adults attended Central Mass MCP's Mosquito Awareness Program. In addition, as part of a service call to determine whether a complaint merits intervention, MCP staff members speak with household members whenever possible to educate them about source reduction. Literature on mosquito biology, personal protection, and source reduction is left with each household at each visit (examples provided in **Appendix 6**). Plymouth MCP has a community liaison who educates boards of health and schools, as well as reinforce knowledge about the Children's Protection Act IPM requirements. In addition, the Plymouth MCP liaison is attempting to interface mosquito control education with the Massachusetts Curriculum Frameworks so that relevant lessons may be taught in public schools. All MCPs have websites that provide a range of mosquito-related information and further educates the public.

A.2. Legal issues influencing mosquito control activities

A.2.1. Children's Protection Act

Chapter 85 of the Acts of 2000 (http://www.massnrc.org/ipm/schools-daycare/child-protection-act-2000/full-text.html) amended the State Pesticide Control Act to regulate the use of pesticides on school property, with the intent of reducing exposure where children live, work, or play. Pesticides are useful on school properties: programs such as outdoor sports, band practice, or other school-sponsored events may be impacted by mosquito annoyance or risk of acquiring a mosquito-transmitted infection. Written notification is required in advance of any adult mosquito[17] pesticide application, specifying dates, locations, product name, fact sheet, EPA registration number, and a statement outlining means of reducing exposure to the pesticide or precautions needed for individuals of special concern. School sites must be visibly posted with information 2 days before and 5 days after. Pesticides may not be applied while children are present. For application in the vicinity of schools or daycare facilities, advance notification must be made to each such facility.[18] CPA has impacted mosquito control with respect to the time and costs associated with notifications, as well as reducing the use of resmethrin (see Section A.1.H.2).

A.2.2. Clean Water Act/National Pollutant Discharge Elimination System (CWA/NPDES) issue. (modified from a Northeast Mosquito Control Association statement).

EPA issued a rule in 2006 that pesticides applied to, over, or near "waters of the U.S." in accord with their FIFRA labels were not "pollutants" under the Clean Water Act, and therefore their application did not require CWA permits. On January 7, 2009, a three-judge panel of the 6th Circuit Court of Appeals in Ohio rejected the rule, siding with environmental plaintiffs that had challenged EPA's authority to issue the rule. The Court did not determine that all pesticide applications are necessarily pollutant discharges, but it did discern three situations in which it believes CWA permits are required:

1 The Court found that biological pesticides are "biological materials" and hence "pollutants" under CWA, and will always require permits for applications to waters of the US. This would cover bacterial larvicides, insect growth regulators, and probably pyrethrin or other botanical adulticide products.

2 The Court found that applications of chemical pesticides that result in "excess" chemical

[17] CPA specifically exempts EPA classified category 4 mosquito larvicides from the notification requirements.
[18] It is recommended to send such notices by certified mail so that receipt by a school or daycare may be proved.

being applied to waters of the US constitute discharges of "chemical wastes" to the water, and therefore will require CWA permits. This would potentially cover any adulticide application with detectible deposition in waters of the US.

3 The Court found that direct aquatic applications of chemical pesticides that result in "lasting residues" in waters of the US are also discharges of "chemical wastes" and therefore require CWA permits.

The Court also determined that pesticide applications are, at the moment of application, "point source discharges," and therefore require permits, unlike "non-point-source" discharges such as runoff. In addition, the Court essentially determined that pesticide applications are pollutant discharges under CWA if either 1) they are biological materials; 2) they are not applications directly to water but result in pesticide in water; or 3) they are applications to water which result in "lasting residuals." The Court also incorrectly claimed that pesticides have long required CWA warnings on their labels - while this is true for concentrated product that may result in accidental effluent, it is not true for end-use pesticides.

This ruling stimulated much discussion regarding the legal liability of MCPs when undertaking their activities during 2009. Clarification was sought by the Department of Agricultural Resources in an April 4 2009 letter to the Municipal Permits Branch of the EPA. On June 8, 2009 the 6th Circuit Court issued a 2 year stay of the decision, thereby allowing MCP activities to proceed for the time being without the legal uncertainties. In the interim, EPA will draft language for a General Permit to cover mosquito control applications. It would be prudent to proactively establish policies and procedures for acquiring CWA permits in the event that the Rule goes into effect inasmuch as many mosquito control activities would be impacted.

B. Detailed description of the mosquito control monitoring program.

MCPs currently undertake surveillance (prospective sampling to detect changes from expected values) for mosquito diversity and density and presence of EEEV and WNV, usually on a weekly basis. Monitoring (evaluation of need for and effects of an intervention) activities comprise (1) larval or adult mosquito counts to determine whether action is warranted as a result of citizen complaint; (2) ad hoc (e.g., product or device quality control; or investigating complaints that a citizen's service request failed to reduce annoyance) or random sampling of treated sites to determine efficacy of larviciding or adulticiding actions. Pre- and post- treatment larval counts are always performed for aerial applications. The methods used are those that are widely used by mosquito control projects nationally, such as counts of larvae from 3 or more dips at specific small pools of water for peridomestic interventions; or a more formal dip station methodology with semi-permanent sampling stations and greater number of dip samples. Adult mosquito sampling is generally accomplished by use of light traps. The 1998 GEIR should be consulted for detailed methods on sampling larvae or adult mosquitoes.

Formal monitoring, analysis of data, and presentation of summaries has to date not been required by SRMCB and does not appear to be a national standard. The BMPs for freshwater and saltwater habitat management are evolving, however, to include standardized monitoring for effects of such intervention on mosquito density. The following discussion seeks to clarify the need for and issues associated with surveillance and monitoring activities.

B.1. Definition of monitoring

Measuring the effects of an intervention provides quantifiable evidence of efficacy and could help improve the implementation of the intervention. Accordingly, all definitions of integrated pest management include monitoring pre and post intervention effects. The word "monitoring" for the purposes of this Update needs definition inasmuch as there are two measurements that need to be taken in the context of mosquito control in Massachusetts. It should be recognized that much anti-mosquito intervention here is at the behest of the taxpayer for annoyance reduction, or to prevent taxpayers from needing to make a request for abatement. Appropriate monitoring, therefore, would document customer satisfaction. One mosquito control project (Central Massachusetts) has undertaken satisfaction surveys of households that have requested abatement. Such surveys could be performed by all mosquito control projects, and utilize methods such as random selection of households to reduce respondent bias. Nonetheless, the nearly universal retention rate of Towns each year in their respective mosquito control projects speaks to customer satisfaction at a broad level, particularly in difficult economic periods such as the current one.

All mosquito control projects in Massachusetts utilize citizen complaints or requests for abatement as data to identify nearby developmental habitats. Longitudinal records of complaint calls or spray requests are mapped; clusters of complaints from more than 1 house in a neighborhood warrant intensive investigation and indeed serve as triggers for intervention. Queries as to time of annoyance can provide information on the potential mosquito species, and thereby, of its developmental habitat. All such information may be used to initiate source reduction.

Monitoring is generally thought to comprise biological evaluation. Service requests are undertaken by personnel who determine whether intervention is needed, either by larval counts, landing rates of adult mosquitoes, or best professional judgement. After treatment, personnel may return to perform larval counts but measuring impact on adult mosquitoes is done randomly or ad hoc. Aerial applications of larvicide are always monitored by pre and post treatment larval counts. The exceptional action of aerial adulticiding for EEE intervention follows protocols (documents 2 and 3, Section E) which specify the nature and extent of monitoring, which also includes ad hoc testing for nontarget impacts. Area wide, truck mounted adulticiding is done based on surveillance and best professional judgement by East Middlesex and Suffolk MCPs. During periods of great mosquito density, Norfolk and Northeast Mass MCPs will switch from service requests to wide area applications for some communities. Sites for such action (usually neighborhood blocks) are identified based on the numbers of mammal biting species found in light traps. East Middlesex, for example, uses 3-5 survey traps in specific neighborhoods based on history. Greater than expected (based on data from previous years) numbers will initiate applications but fewer than expected mosquitoes provides evidence that additional application is not necessary.

B.2. Definition of surveillance.

"Surveillance" comprises systematically measuring the densities and diversity of mosquito populations over time to identify short term and longterm trends that may play a role in the decision making process for a given year. For example, if larval dipping sites sampled during the spring in Town A indicated a 50% increase in *Aedes canadensis* over the previous year, but those in nearby Town B and C demonstrated no change, proactive efforts of intensified larviciding in woodland sites might be undertaken in Town A to reduce the possibility that *A. vexans*, which may breed in the same woodland pools as *A. canadensis*, may also have undergone an increase.

The same surveillance samples (adult mosquitoes only) obtained for measuring trends in mosquito demography can be used for arboviral testing to determine if, where and when WNV or EEEV transmission may occur. Indeed, there is some suggestion that the word "surveillance" should only apply to public health aspects of mosquito control (http://www.astho.org/pubs/FinalReportPDF.pdf.) Surveillance sampling, however, rarely serves the purpose of monitoring for the effects of intervention unless trap or larval dipping sites are near source reduction sites. Surveillance data is generally summarized in real time (examples of such reports from MCPs may be found at http://www.massnrc.org/ncmcp/Weekly Mosquito Surveillance.htm), and could serve as an action threshold for intervention if the sampled sites are near high densities of residences. The State Laboratories Institute at MADPH has maintained a series of longterm (>30 years) surveillance sites for arbovirus (mainly EEEV) transmission (Hachiya et al. 2007), particularly in Southeastern Massachusetts. Thus, MCP surveillance data complements that of DPH and might demonstrate state-wide trends in the density of specific mosquito species.

In summary, "surveillance" attempts to longitudinally document trends within established sampling sites, with the purpose of detecting change. "Monitoring" can have different meanings depending on the context. Monitoring can refer to immediate evaluation of efficacy of adulticiding or larviciding. It would also be appropriate to monitor customer satisfaction. Monitoring for adulticiding and larviciding has a short time scale, days to weeks. Monitoring for source reduction has a longer time scale, weeks to months to years.

B.3. Discussion of comments from the Secretary's Certificate.

Important issues raised by the Secretary's Certificate include (1) the need for "comprehensive monitoring" to "document effectiveness"; (2) a query on the nature of "action thresholds"; (3) a suggestion that findings (data) need to be analyzed and presented; (4) the extent of "monitoring" by MCPs; (5) query on details of monitoring for freshwater and OMWM; and (6) a suggestion that monitoring information from mosquito control programs from other states may be useful. These issues are addressed in B.3.A. through B.3.D.

B.3.A. Comments on "comprehensive monitoring".

Comprehensive monitoring could be interpreted as "research standard". Mosquito sampling, like any other arthropod sampling, is complex (Service 1993) and requires careful experimental controls because of the important influence of environmental factors on the development of mosquitoes. A research standard of monitoring takes great care to associate cause and effect and exclude confounding by other contributory factors. For example, Site A is to be larvicided to abate nuisance. A rigorous dipping strategy is used to precisely quantify (mean number of larvae per dip with a narrow 95% confidence interval) the larvae prior to treatment. We assume for the sake of argument that all larvae are the same instar and that they will be susceptible to the larvicide (i.e., they are not 4^{th} instar; in reality, the assumption is simplistic because larval development is rarely synchronous and virtually all instars may be found simultaneously).

Larvicide is placed in Site A. The same rigorous sampling strategy is used each day for 3 days thereafter and it is determined that on the 3rd day after treatment, there are 80% fewer larvae per dip. It is, however, difficult to attribute the reduction in Site A to larviciding. No experimental control within Site A would be possible: we wish to reduce the emergence of adult mosquitoes from Site A and we treat all of the perimeter where larvae are detected. We cannot use a nearby body of water where placebo would be placed, to control for the effects of weather (perhaps the temperatures were way above normal, accelerating development and emergence, leaving fewer larvae in the water to be sampled), because ultimately the goal of the exercise was to abate a nuisance and any nearby body of water containing larvae would have to be treated; and, the two bodies of water may not be identical in biotic or abiotic factors that influence larval development. This example illustrates the logistical problems that comprehensive monitoring for each and every activity would entail. A typical mosquito control operation simply seeks to document that if Site A received larvicide, there should be some evidence that fewer larvae are there 48 hours later using simple before and after counts. At the very least, what could be a 10 minute service call might need to turn into a half hour or likely more if MCPs were held to a research standard for monitoring.

Evaluating the effectiveness of interventions on mosquito populations needs to consider the transient nature of most mosquito control activities on a dynamic biological entity. Longterm (more than a year or two) suppression to the point that mosquitoes are a minimal nuisance or public health threat is difficult to achieve without intensive control efforts. And, any such success requires a maintenance phase. One of the few examples of longterm success is that of the African malaria vector, *Anopheles gambiae*, which was inadvertently introduced to Brazil in 1930. It was actually eradicated by 1940 but only by the creation and funding of a special 4000 man force empowered to use draconian measures that infringed on human rights (Soper and Wilson 1943). Mosquito control can only temporarily abate nuisance for a discrete period of time. New broods of mosquitoes are continuously produced in any site, thus repeated intervention is required. Longterm changes in the demography of any mosquito population will not generally occur without greatly intensified larviciding or adulticiding, which can have environmental costs when intensified. Longterm changes may be possible in very specific instances, such as by undertaking Open Marsh Water Management for saltmarsh mosquito abatement (Rochlin et al. 2009). Thus, activity undertaken by mosquito control programs in Massachusetts and elsewhere in the U.S. generally produces transient results. A single adulticiding in one neighborhood may reduce annoyance to zero for a few days, but the following week may see the return of as many or more mosquitoes in the same site as a new brood of larvae matures. Although temporary, the effects of proactive or reactive mosquito control improves the quality of life for a measurable amount of time. In addition, suppression at any given time may have delayed effects such as reducing density later in the year or in the next year for certain mosquito species which lay dessication resistant eggs that hatch upon reflood conditions (http://www.rci.rutgers.edu/~insects/mosclass.htm).

B.3.B. Action thresholds.
With respect to "action thresholds for management decisions", MCPs have their own criteria (see Section C.5.) for initiating activity. Qualitative thresholds (number of larvae per dip, number of human biting mosquitoes per trap or landing, typical methods for generating indices of abundance, even best professional judgement) are currently used in determining whether an

annoyance reduction request requires action. Although a "human annoyance threshold" (HAT) would be a useful index, a formal study such as Carrieri et al. (2008) would be needed to establish HAT for representative Massachusetts communities. Thus, HAT is currently based on MCPs' historical experience with local residents. It is likely that socioeconomic status greatly influences whether a household considers its surroundings to be intolerable and in need of annoyance reduction.

B.3.C. Need for and venue of presenting data analyses.
"Analyzing and presenting the findings" is not a standard national practice for mosquito control. Representative data (pre and post intervention) that have been provided by some of the MCPs for this Update suggests that practices and procedures achieve great efficacy. Requiring MCP Annual Reports to state "of x applications of larvicide, y % reduction was observed on average with [a-b] 95% confidence interval" or a similar analysis for each of its activities comprises a large resource burden which would need to be justifiable.

Data that has been provided for this Update by 5 of the 9 MCPs (provided in **Appendix 3**) demonstrates that pre and post-activity measurement is always undertaken as a standard of practice for aerial larviciding. Some MCPs have undertaken random or ad hoc pre and post treatment sampling for larviciding and adulticiding service calls. The Freshwater Best Management Practices (BMP) document that was recently adopted (http://www.mass.gov/agr/mosquito/docs/mepa/Document_2_Freshwater BMP to MEPA_ Oct_24_2008.pdf) specified the need to document a problem before starting any project but does not explicitly state that effects on mosquito density (short or longterm) be measured nor the extent of the data required. MCPs do not appear to have much data from past efforts that addresses the efficacy of freshwater source reduction[19]. A new mechanized wetland management post-monitoring guidelines document has been developed and will be attached as an addendum to the existing Freshwater BMP (**Appendix 7**). Thus, it is likely that data will be accumulated in the future.

B.3.D. Extent of monitoring
All MCPs engage in pretreatment sampling for all larviciding (larval dip counts[20]; most tend to use O'Malley 1989 for guidance) activity to ensure that their activities are required. Some have randomly performed pre and post activity counts to ensure that their practices and procedures are working to expectation. The data that has been and is collected, however, may or may not be formally analyzed or presented depending on the availability of resources.

Post-treatment measurements for adulticiding are usually done on an ad hoc basis (light trap/gravid trap catches or landing rates; light traps and gravid traps are standard devices, see Service 1993 or Reisen et al. 1999, 2000). Adulticiding efficacy is informally estimated by the

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[19] Indeed, no peer reviewed literature was found documenting the efficacy of freshwater habitat management on reducing mosquito density, other than 1 paper on vegetation removal (Lawler et al. 2007). Historically, control of anopheline mosquitoes to abate malaria transmission has been accomplished by such methods, but such reports are tangential to the objectives of annoyance reduction and arbovirus risk reduction here, which are due mainly to aedine or culicine mosquitoes.

[20] A standard 250milliliter white plastic cup dipper is quickly skimmed under the surface of a body of water to capture larvae that are resting near the surface. Larvae are identified by visual inspection to genus and stage of development, and counted. Replicates (3 or more) are usually from the same body of water in rapid succession.

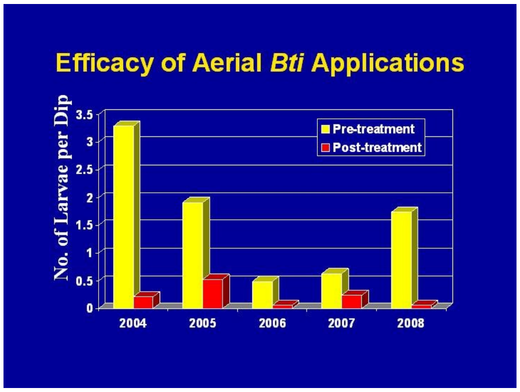
immediate absence of complaints from neighborhoods where treatment had been undertaken. Post-adulticiding monitoring is hindered by the great variability inherent in sampling adult mosquitoes by trapping. This is due to the nearly continuous emergence of adult mosquitoes from nearby breeding sources as well as immigration from more distant sites. In fact, typical measures of adulticiding efficacy often use caged mosquitoes to reduce the effects of these variables (Mount 1998) but this experimental design would not be practical for daily mosquito control activities. Landing rates would be most relevant for documenting annoyance reduction, but MCP manpower is limited to do this for all applications. Landing rates, in fact, are discouraged when viral activity has been documented due to the possibility that staff might be at risk of exposure to infection.

Because a large proportion of current MCP activity appears to be consumer driven (annoyance reduction requested by citizens residing in member towns), the most relevant monitoring program would be a customer satisfaction survey. For example, in 2008, Plymouth MCP recorded 14,346 requests for service and Central Mass MCP 10,650. Even large scale interventions such as open marsh water management could be evaluated on the basis of area residents' satisfaction given that such sites serve as a source of pests such as saltmarsh mosquitoes even a few miles away. If there were no complaints or suggestion that pest infestations were likely to have originated in such a site, there would be no need to intervene.

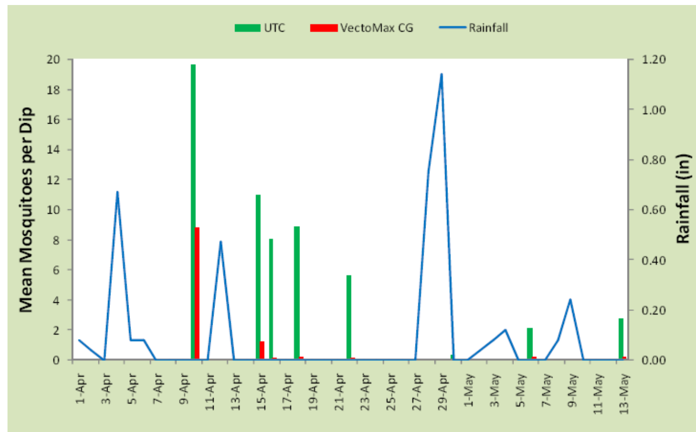
Currently, only one MCP (Central) performs such a customer satisfaction survey and the results from its 2008 survey are provided (**Appendix 8**). Briefly, of 5088 adulticiding service calls, 1000 were chosen for a postcard mailing, distributed proportionally according to Town representation for all the service calls. The postcards invited households to participate in an online survey for which a blind weblink and unique identifier was provided. A response rate of 22.4% was recorded. Of the 224 households responding, 217 answered the question "did our application make your area better, worse, or had no effect" and 85.3% responded that the action made things better. Two thirds of the respondents indicated relief for a week or more. Interestingly, the estimated cost of $2.00-4.00 per person per year was deemed sufficient by 83% with only 0.5% considering the sum to be excessive. Of 220 respondents, 91.8% indicated that they were 'happy" with the service. Even recognizing that this survey may be burdened by respondent bias, and does not represent a random survey (a random digit dialed telephone survey of all citizens including those that did not request services would be more representative but certainly would require much more effort), it is clear that for 2008 (and for the two other years that Central has undertaken such a survey) there is excellent customer satisfaction. The significant retention rate of Towns as members attests to the degree of general satisfaction with the MCPs' efforts to abate nuisance, particularly in difficult economic times.

B.3.D.1. Examples of data provided by MCPs

Large amounts of data have been collected by MCPs for their own use. Indeed, Plymouth, Central, Norfolk, and Northeast provided examples of Excel files containing pre and post larviciding or adulticiding data (mainly for their aerial larviciding programs) from several representative years and these are attached as **Appendix 3**. Central has summarized efficacy of certain of their activities for presentations at local or national society meetings (**Appendix 9**). Cape and Suffolk provided limited data but do collect it in the course of evaluating sites for intervention as well as gauging efficacy by post-intervention sampling. Even East Middlesex, which has fewer than 5 FTEs, always evaluates the efficacy of aerial larvicide applications; evaluates larval catchbasin density; and preapplication larval surveys for ground larval control applications. The MCPs with large volumes of data have not fully exploited it nor have summarized it for annual reports; most tend to review the data to qualitatively evaluate efficacy.



A representative analysis for 2008 monitoring data (Central Mass MCP) demonstrates that larviciding was extremely effective: for 162 service calls, the mean number of larvae per dip was 7.13 (95% confidence interval 6.32-7.94) whereas one week post-treatment the mean number of larvae was 0.43 (0.13-0.73). East Middlesex MCP provide an excellent graph of the efficacy of their spring aerial larviciding application (left panel) and Norfolk MCP demonstrates a thorough analysis of a 2008 trial using Vectomax CG by aerial application (right panel) in which rainfall influence is examined simultaneously with treated and untreated sites over the course of several weeks to measure the effect on multiple broods of spring melt mosquito species. The aerial larviciding programs have consistently documented pre and post treatment data and demonstrated great efficacy.



Thus, most MCPs have been and are continuing to appropriately monitor the results of their larviciding activity as a means of checking procedures and equipment as well as determining whether additional treatment might be required. All MCPs have thresholds for action based on a pre-treatment assessment (Table 5).

MCP	**Larval threshold**	**Adulticide threshold**
Berkshire	5 per dip	5-10 per minute landing rate
Bristol	>1 per 5 dips	5 per light trap
Cape Cod	any *A. sollicitans**	(adulticiding not done at Cape Cod MCP)
Central Mass	>1 per 5 dips	>1/min landing rate; >5 human biters per trap
E. Middlesex	1 per 10 dips	100 mammal biters within any one light trap
Norfolk	any larvae	>5 human biters per night in light traps
Northeast	any larvae	3 requests from residents of same street
Plymouth	>1 per 5 dips	>5 human-biters/light trap/night; >1/min landing
Suffolk	any larvae	"enough to make you go indoors"; >200/trap-night
*other than *A. sollicitans*, 5 per dip		

There is some variability in action thresholds, although most are in the range indicated by the available resources (e.g., http://www.ipm.illinois.edu/livestock/insects/mosquito/index.html or the Suffolk Co. NY GEIS http://www.suffolkcountyny.gov/health/suffolkvectorplan/pdf/final/Revised%20Long-Term%20Plan.pdf Interestingly, few online resources provide actual numerical thresholds; see http://www.astho.org/pubs/FinalReportPDF.pdf; http://www.state.nj.us/dep//enforcement/pcp/bpc/ipm/mincrit_mosquito.pdf) Light trap based thresholds need to be interpreted in the context of several variables, which include (a) type of light trap (CDC vs New Jersey vs ABC[21]); (b) with or without $C0_2$ supplementation; (3) placement at eye level as well as at tree canopy; (4) mammal vs. human biters (not all mammal biters will bite humans). Gravid traps to estimate densities of ovipositing *Culex* spp. (*C. pipiens, C. restuans, C. salinarius*) are also used by all MCPs[22] but it is not clear that data from such traps is used to determine whether an action threshold has been achieved. Thresholds for both larviciding and adulticiding may also be modulated by best professional judgement of the staff conducting the service call, and include historical records, weather conditions, or an overall impression based on all of the criteria. Such flexibility is critical to effectively target the very local nature of most mosquito infestations. Note that an action threshold based on standard larval dipping would not apply for certain mosquito species such as *Coquilletidia perturbans* (larvae which cannot be sampled by dipping due to their residence in cattail root systems), underscoring the importance of flexibility based on local knowledge.

Source reduction in wetlands, including open marsh water management, may have different thresholds and such measurements are undertaken at different scales such as 1 dip station per 250 acres as is done by Plymouth and Central MCP; or 3 dips within a 30 yd radius of each of 10 permanently sited dip stations for Northeast. The latter specifies that surveys must be undertaken at weekly intervals for 2-5 months. Note that action thresholds or pre and post monitoring of interventions targeting wetlands may not always be appropriate inasmuch as an important objective is proactive management, that is, acting before a problem exists.

A similar conundrum (i.e., how to monitor a proactive strategy) exists for treating catch basins with Altosid: methoprene is active against all pre-adult stages and can be placed to prevent eggs from giving rise to larvae. There are no good ways to sample for eggs within catch basins, thus preemptive treatment in May or June is done without pre and post monitoring; random sampling for both pre- and post- is then done during the height of mosquito season when larvae may have washed into such catch basins from other developmental habitats, or been produced in the interim between Altosid or Bs applications when some breeding would occur.

B.3.D.2. Extent of monitoring for freshwater and open marsh sites

Specific recommendations were not presented in the Freshwater BMP for the number and location of monitoring sites where freshwater or open marsh water management is undertaken. Accordingly, very little data was provided by MCPs to document the extent of monitoring for freshwater sites. A standardized protocol has been developed for mechanized wetland management activity pre and post-monitoring, and will be incorporated as an addendum to the existing BMP (**Appendix 7**). Monitoring for OMWM activities is currently under discussion as the OMWM BMP is finalized but is as yet unavailable.

[21] Details on how the traps work may be found in the 1998 GEIR or in the SRMCB Operational Response Plan to reduce the risk of mosquito borne disease in Massachusetts of October 22, 2008.

[22] Gravid traps are mainly used to sample mosquitoes that are parous, that is, have had a chance to acquire an infectious bloodmeal and may be carrying virus. These *Culex* spp. may be effectively sampled by light trap as well.

A search (website or published literature) of mosquito control programs in other states failed to find recommendations for extent of sampling, modes of analysis, or intervention efficacy targets for freshwater wetlands management projects.

There is some indication that "monitoring" and "action thresholds" as specified in the Certificate may allude only to wetlands management (freshwater or open marsh). Comprehensive wetlands management monitoring, to include not only mosquito parameters (diversity, density, population trends) but also effects on nontarget species including plants, as well as hydrological concerns, appears to be well beyond the capacities of MCPs as currently funded. The utility of observing, for example, that 5 "minnows" were seen in 5 minutes would likely not be considered to be useful by stakeholders interested in fish ecology. Monitoring of flora and fauna should be performed solely by professional wetlands ecologists, perhaps by leveraging support from other state agencies such as MassWildlife. Hydrological measurements should be performed by personnel with the appropriate training and expertise.

If current action thresholds for service calls or best professional judgement are not acceptable as part of the decision making for undertaking wetlands management, establishment of new recommended thresholds would require extended surveys and analysis. The Executive Summary for the 1998 GEIR in fact recommended finding funding so that SRMCB can hire a professional field biologist who can undertake some of these studies; additional recommendations included a minimum operations budget of $50,000 a year[23] to specifically support such research; as well as a competitive grant program to support IPM related research. Such funding has not been allocated and this, in part, may help to explain why there is a perceived lacuna with respect to oversight related to wetlands management or standard service call activities. It should also be noted that much wetlands work is proactive and thus no hard data (mosquito density estimates over a long period of time) may be available. Decisions for undertaking wetlands management comprise historical records of complaints or density measurements if available; requests from towns or state officials; or best professional judgement by MCP staff.

It is likely that additional requirements for permitting or review, enhanced or comprehensive monitoring, or operational restrictions would increase costs of wetlands management as it is currently undertaken. Given annual MCP budgets that are not matching standard cost of living adjustments (similar to all other State programs), source reduction may be undertaken less frequently with the consequence of requiring more larviciding and adulticiding.

B.3.D.3. Efficacy of activities and modification of practices and procedures

"Monitoring" should not be conflated with "surveillance." The longterm sampling sites for surveillance objectives may or may not provide data that bears on whether current practices and procedures are effective. All MCPs undertake pretreatment surveys for virtually all larviciding and adulticiding, as well as random or ad hoc posttreatment surveys as a check of their practices and procedures. However, such data has not been formally analyzed or presented in annual reports due to resource constraints. Such data is collected for practical operational uses: products or machinery or staff practices are tested on a random basis to determine whether they are functioning according to specifications. However, modifying best management practices would

[23] Such studies would now likely require a minimum of $100,000 for FTE and $50,000 for operational budget.

generally be as a result of peer reviewed recommendations at a regional, state (SRBMC), or national mosquito control organization level or by recommendation of product or equipment suppliers.

The Certificate stipulates that “the effectiveness and impacts” be measured with the aim of modifying Best Management Practices. As mosquito control in Massachusetts is currently structured, the stipulation has been met inasmuch as individual MCPs are indeed monitoring and have been doing so. No MCP has been able to monitor every activity for efficacy and is unlikely to have resources to do so in the future. Existing data is essentially raw; accessibility in the form of graphical presentations or simple statistical evidence that interventions are successful would be useful from the standpoint of public transparency. On the other hand, because mosquito infestations develop due to local conditions, provisions of average counts (larvae or adults) over the MCP or even Town might not be representative and indeed would be likely to provide estimates with the variance greater than the mean. Analysis by neighborhood would likely be burdensome with respect to staff time and the information derived of limited value.

SRMCB's "mosquito control program" comprises the 9 MCPs but SRMCB itself has no field operations, analysis, or research component. The mission of SRMCB (as summarized in the 1998 GEIR) does not appear to include data analysis and in fact, no FTE support is evident to accomplish such a task. At the very least, additional FTEs are required to add biostatistical support, and in particular, professional entomological expertise to interpret and guide analysis. Alternatively, MCPs could summarize such data for the annual report with some targeted questions as to whether any practice or procedure demonstrated suboptimal or otherwise unexpected performance.

The scope and endpoint of such data gathering and analysis other than what it is currently used for is not clear. National standards for efficacy or impact do not exist. Perceptions of efficacy might differ depending on whether customer satisfaction is valued or whether biologic efficacy needs documentation. It cannot be overemphasized that larviciding and adulticiding are temporary measures. Sequential broods of emerging mosquitoes require repeated applications for management. In addition, individual mosquito species differ with respect to their seasonal abundance; one could achieve maximum control for epidemiological week 30 but be faced with a new emergence of a different species in week 32.

OMWM and other forms of source reduction, and to a certain extent public education to foster peridomestic source reduction are longterm efforts, in which measurable effects might be seen only after many years. Accordingly, monitoring might need to be extended in duration; effects might not be observed until sites reach an ecologic equilibrium. Operations manuals incorporating the Freshwater BMP (http://www.mass.gov/agr/mosquito/docs/mepa/Document_2_Freshwater%20BMP%20to%20MEPA_%20Oct_24_2008.pdf) from Plymouth, Central and Northeast MCPs specify that any water management (fresh or saltwater) must be monitored for two years post-intervention.

B.3.D.4. "Monitoring studies" from other states

This Update has not identified recent peer reviewed publications of "monitoring" studies undertaken in the Northeastern U.S. The typical practices and procedures for mosquito monitoring are well known to mosquito control workers throughout the United States (O'Malley 1989; Service 1993; Reisen 2000; CDC 2003). Peer reviewed publications tend to focus on novel observations or improvements or analysis of practices or procedures by means of research. Research is a luxury for most MCPs anywhere in the U.S. Thus, there is little impetus and no resources to support publishing analyses of service call data. However, one important source of supplementary information may derive from continuing education by attending professional meetings. Regional associations such as the Northeast Mosquito Control Association routinely present and share experiences with current and new practices and procedures. It is critical that all full time staff, from the director of MCPs to the actual service staff, attend the NMCA meetings regardless of venue for the purposes of continuing education, to share their experience and to benefit from that of similar activities in neighboring states.

The methods used by MCPs are in use throughout the US (Mount 1998; Rose 2001; http://www-rci.rutgers.edu/~insects/bmpmcnj.pdf; http://entnemdept.ifas.ufl.edu/fasulo/vector/manual.htm) and indeed, at least for larviciding and adulticiding, the materials and equipment are generally supplied to mosquito control projects across the U.S. by one of three large national companies focusing on mosquito control: Clarke Mosquito Control, Adapco, and B&G Chemical.. Standard operating procedures for pesticide use as well as that for any machinery are also provided by these companies. Pesticide use for mosquito control is highly reviewed and regulated by the U.S. EPA (http://www.epa.gov/pesticides/health/mosquitoes/) under FIFRA, with strict labeling comprising directions for use and any precautions. Any deviation from expected results would be due to (1) employee error; or (2) site specific issues, for example, unexpected temperature changes or most likely, local synecology[24] of the target mosquito species.

C. Annual report of mosquito control activities and monitoring results.

The Certificate stipulated that the Proponent should identify a process to publish and seek annual public review and comment of its mosquito control and monitoring activities. Annual reports for each MCP have been compiled for 2007 and 2008 and these documents are available online [http://www.mass.gov/agr/mosquito/annualreports.htm; 2008 reports are provided in **Appendix 10**]. These annual reports are provided to all of the Boards of Health of their respective member towns, thereby fulfilling the stipulation that an annual report be provided to municipal offices and public libraries for each MCP's member towns. The local Board of Health is the most appropriate repository for such information inasmuch as they generally decide on Town membership in MCPs. Additionally, these documents are available online via the SRMCB website.

The agenda for and scheduling of an annual meeting for public review and comment is under discussion by SRMCB and the MCPs. Tentatively, this would entail an annual review night for each of the 9 MCPs, perhaps in February or early March. SRMCB would introduce itself and describe their mission, provide a brief overview of statewide mosquito control, and subsequently the MCP would summarize their annual report and entertain questions.

D. Best Management Practices (BMPs), policies and standards pertaining to the Proponent's mosquito control and monitoring activities in salt marsh habitats (Open

[24] Synecology: the relationships between local communities of diverse organisms.

Marsh Water Management).

The OMWM BMP is being finalized by the Open Marsh Water Management (OMWM) Monitoring Standards Work Group to complete the OMWM Standards. The Northeastern Massachusetts Mosquito & Wetland District OMWM program has not initiated any new projects since 2008 pending resolution of the OMWM standards and the receipt of various federal and state approvals/permits including Coastal Zone Management (CZM)'s consistency review. Good progress is being made and a draft revision of the March 2008 OMWM standards which incorporates the monitoring techniques and other recommendations from the OMWM Monitoring Standards Work Group became available in June. However, there are some issues that still need attention and review. The proposed changes to the March 2008 OMWM standards need to be weighed in terms of overall cost effectiveness and implications for the future of this program. Also, the timing of the draft during the seasonal operations pushed further reviews to later in the fall after the mosquito season .

Nonetheless, the MCPs' draft text ("Immature Mosquito Development Habitat Sampling") has been submitted to the workgroup. MCPs will be allowed a trial period to field test the protocol in order to ensure that the sampling is effective and feasible before the protocol will be added to the OMWM Standards. It is the Board's goal to complete the revised standards by spring 2010 and pursue the necessary federal/state permits.

E. Plans, analyses, policies and management practices that have been developed and implemented since the 1998 GEIR was filed.

On November 26, 2007, as part of the 1st GEIR update, SRMCB provided important documents including best management practices and operational guidance for mosquito control activities in freshwater wetlands. These included the following, all of which are attached within **Appendix 10** and are also available online [http://www.mass.gov/agr/mosquito/mepa_filing_102408.htm]. In addition, Appendix 10 provides other plans, analyses, policies, and management practices developed by SRMCB since that time.

1. Massachusetts Best Management Practices and Guidance for Freshwater Mosquito Control, (Revised October 24, 2008);

2. Operational Response Plan to Reduce Risk of Mosquito-Borne Disease in Massachusetts, (Revised October 22,2008);

3. 2008 Massachusetts Arborvirus Surveillance & Response Plan (MA Department of Public Health (DPH));

4. Pesticide Related Illness Surveillance: Summary Report, September 26, 2006,(DPH)

5. EEE Adulticide Spraying (Round 2) , September 1 1,2006 (DAR SRMCB)

6. EEE Aerial Spray, August 18, 2006 (DAR SRMCB)

7. Choice of Anvil 10+10 for Aerial Mosquito Control, July 28,2006, Michael Celona

8. Final Report to EPA for use of Anvil 10+10 in MA, March 6,2007, (DAR SRMCB).

9. Memorandum of understanding (MOU) with MassWildlife for intervention in rare and endangered species habitat, 2009

10. Open Marsh Water Management in Northeastern Massachusetts from 1998-2008: A Ten Year Review

11. Cranberry Sampling Study for Anvil 10+10 Southeastern Massachusetts prepared by the Center of Environmental Health MA Department of Public Health

12. State Reclamation and Mosquito Control Board Mosquito Misting Systems Position Statement

13. Adult Mosquito Control Pesticide Label Compliance Policy Pertaining to the Protection of Bees by the State Reclamation and Mosquito Control Board

14. Methoprene, A review of the impacts of the insect growth regulator methoprene on non-target aquatic organisms in fish bearing waters (Ver. 2.0) For the Massachusetts Pesticide Board Subcommittee

15. State Reclamation and Mosquito Control Board Administrative Policies such as the Employee Time Off Policy, Budget Policy, Budget Q & A, Motor Vehicle Accidents, and Commissioner Indemnification

16. Adult Mosquito Control Intervention Parameters, and Scientific Data to Support Effectiveness of Spraying; and

17. Massachusetts Mosquito Fact Sheet

F. Update of coordination efforts with state and local agencies.

SRMCB and the MCPs collectively have worked closely with Coastal Zone Management on drafts of the Open Marsh Water Management best practices manual. In addition, strong collaboration with the Department of Public Health is demonstrated by the completion and filing of operational responses and arbovirus surveillance and response plans during the 1st GEIR update. Finally, an MOU has been executed with MassWildlife concerning intervention in rare and endangered species habitats.

Opportunities to leverage agency resources have not yet come to fruition. Given budgetary constraints for each MCP, such resources would be particularly useful for longterm monitoring of source reduction in wetlands, specifically for nontarget effects on flora and fauna that are not within the expertise of MCP staff.

G. A workplan and schedule for developing additional information and procedures to assess and guide SRMCB's mosquito control program.

As stated in section D , SRBMC's main goal will be to work with the Open Marsh Water Management (OMWM) Monitoring Standards Work Group to complete the OMWM Standards. SRBMC will continue to seek improvements in Massachusetts mosquito control practices.

H. Literature review of alternatives to mosquito control practices suggested by comments received on 1st GEIR Update.

Many of the comment letters referred to alternative methods for mosquito control, implying that the full set of available options were not being used by MCPs. Accordingly, we provide a summary of literature reviews for each such method. Based upon the peer reviewed published literature[25], it seems unlikely that any of these suggestions could replace any of the activities currently undertaken by the MCPs given a lack of documentation regarding their efficacy at either short or longterm scales of analysis.

Some alternatives may have merit and may function well as supplemental or integrated components, but there is no evidence to date that any such alternative might replace the current mosquito control system. Many of these approaches have evolved recently, in conjunction with such events as the introduction of West Nile virus, as the general public has become more aware of the potential dangers of mosquito-transmitted infection. In addition, societal awareness of potential environmental concerns have driven a desire for alternative and ecologically friendly methods of managing our environment. Because they have been recently developed, the efficacy of some of these alternative approaches have yet to be thoroughly investigated. In addition to questions of efficacy, the effects of each intervention and the potential unintended impact on the environment must be considered. Some of the suggested alternatives may have even more nontarget impact than do any of the current modes of intervention.

There is much conflation by commenters of measures that can be undertaken at individual levels with those targeted to a larger hierarchical level such as a neighborhood or community. Although some individual measures such as judicious use of repellants might be extrapolated to entire educated communities, others such as the universal deployment of mosquito magnets would appear to be logistically and economically burdensome.

H.1. Automated misters. Within the last several years products aimed at residential use have appeared on the commercial markets which automatically deliver pesticides in aerosols. The concept is to provide a region of protection by periodic applications of synthetic pyrethrins often around the perimeters of a back yard. The system includes a multiple fixed nozzles connected by tubing to a reservoir containing the pesticide. Periodic pumping of the pesticides through the nozzles is controlled by a timer which can be programmed to repeatedly deliver the pyrethrins

[25] **Appendix 11** contains details of the literature search for each of the 9 alternatives that are discussed, as well as abstracts for the "hits" that were identified during the searches. An executive summary of the searches is also provided in Appendix 11.

based optimal times of mosquito activity. Advantages to such a system include the ease of use coupled with minimal periodic maintenance. In Massachusetts, SRMCB has issued a policy discouraging the use of automated misters because they apply pesticide indiscriminately, not as a response to mosquito monitoring or citizen complaints.

This concept of automated application of pesticide has been used in agricultural settings for several decades especially in areas where pest species affect livestock (Sheppard et al. 1989). Concerns were raised based on the automated nature of pesticide release without a human oversight and surveillance (http://ipm.ifas.ufl.edu/applying/methods/chemical/mosquito.shtml), who pointed out that an understanding of the mosquito species composition and biology is critical to an effective management program. In addition the application of pesticide must consider environmental factors that insure the proper dispersal of the agent. Cilek et al. (2008) evaluated one such system and observed that the effective reduction was species specific and the efficiency highly variable. They also concluded that the reduction when observed was achieved by direct contact with the insect and not a residual effect on resting substrates.

Cilek at al. (2008) also point out several additional areas of concern focusing on potential detrimental effects on non-target insects, potential detrimental effects on human health, distribution of application based on environmental factors and potential for the emergence of insecticide resistant mosquito or other flying pest populations. In a livestock setting, insecticide resistance developed after only two years. Due to the relatively new nature of this study, relatively few research studies have been conducted to evaluate the technology. However, it is clear that such an unattended automated system is a poor substitute for a coordinated pesticide control program.

H.2. Garlic extracts. Garlic has long been thought to provide some personal protection from biting insects and ticks (http://www.ext.colostate.edu/safefood/newsltr/v8n1s07.html; Stjernberg and Berglund 2000). Diallyl sulfides from garlic extracts are active larvicides in vitro, with activity at 5 ppm (Amonkar and Banerjee 1971). A garlic extract based perimeter spray ("Mosquito Barrier") is available and has been used as a nontoxic alternative to the typical pyrethroids or organophosphates. EPA classifies garlic oil or extract to be a minimum risk and exempted under FIFRA (http://www.epa.gov/oppbppd1/biopesticides/regtools/25b_list.htm), thus commercial sales as a pesticide would be legal. However, field based, peer reviewed trials for the utility of such sprays have yet to be done. Little is known about the duration of efficacy and timing of applications, nor on nontarget effects; garlic-derived sulfides are active against other arthropods (Amonkar and Banerjee 1971) such as aphids, caterpillars, and beetles. In the absence of such data, the role of garlic extracts in integrated pest management remains unclear.

H.3. Traps. For the last decade, there has been considerable attention paid to mosquito trapping as a control method (Brown et al. 2008; Kline 2002; Dennett et al. 2004). Products designed for residential use have been developed that catch large numbers of mosquitoes. The product leader in this category has been the MosquitoMagnet. This trap catalytically burns propane to generate carbon dioxide, heat and moisture, all mosquito attractants. In addition to the generation of these attractants, usable energy is generated by this catalytic combustion. This energy is subsequently used to power fans that disperse the attractants in a plume downwind and fans that aspirated and contain the attracted mosquitoes. Additional chemicals attractants can be supplemented to the plume to further augment trap catch or fine-tune the attraction to specific target species. These supplemental compounds currently include 1-oceten-3-ol, lactic acid and ammonia. Attractant compounds are released from the trap and attract mosquitoes which on approach are sucked into the trap where they desiccate. A typical BBQ size propane tank can run the trap continuously for up to 28 days. The traps are " specific" in the types of insects attracted, collecting almost exclusively female biting insects including, mosquitoes, biting midges (Mands et al. 2004; Cilek 2005), sandflies, blackflies, some tabanids and soldier flies. The underlying premise of effective operation for these traps is twofold. First, the traps provide relatively immediate relief by collecting large numbers of biting female flies, which are actively host-seeking. Second, over time, by collecting host-seeking females, the traps should reduce the egg-laying population. Placement of the traps is critical with regards to emergence sites and wind. Traps can be deployed alone as a part of a trap barrier as well as other configurations.

The efficacy of the traps is still being evaluated. Some studies suggest both an immediate relief and long-term effects (Kline 2007), while others show less success (Cilek 2005). Clearly, their efficiency ultimately depends on site placement, the targeted pest species and intangibles associated with the species composition and the site. Although and interesting and potentially useful tool, especially for survey purposes (Ritchie et al. 2007), their role as a control device cannot currently replace other conventional mosquito abatement practices.

H.4. Electrocution Grids or "Zappers". Bug zappers have existed on the commercial market for several decades. The basic concept is to attract the insect to a point inside an electrified metal grid. The common attractive source has been an ultraviolet light. As the insect move towards the light, it encounters the grid and is electrocuted usually resulting in an audible "zap" sound. These products are often purchased to alleviate biting fly problems. However, studies on such electrocution grids where UV light is the lure indicate that of those insect electrocuted, a small proportion (0.22%) were biting flies (Frick and Tallamy, 1996). The authors suggest that exhaled carbon dioxide is far more attractive that the light lure in the trap resulting in most biting insect being attracted to the human. Heinen et al. (2003) also showed that many more non-target insect were killed as compared to biting insects. In another study (Nasci et al., 1983), a similar UV light electrocuting device failed to affect mosquito biting rates. More recent traps utilize additional lures in an effort to overcome this problem.

It is clear that if only a small proportion of target insects was electrocuted, the great majority of insect killed were non-target. Many of the non-targets were probably beneficial insects who alone or as part of the food chain contribute to the environment.

H.5. Predators (dragonflies, bats, fish)

Although the use of natural mosquito predators has been suggested as complementary or alternative methods for mosquito control, there is little or no peer reviewed evidence of their efficacy in annoyance reduction or suppression of public health risks.

H.5.A. Dragonflies. Many aquatic insects spend considerable portions of their life cycle as subadults. Many such subadult insects are predacious (Mogi 2007). We found relatively little published work addressing the role of predacious insects as they relate to Massachusetts or even the Northeast. Much of the basic work has been done outside the country (Chatterjee 2007; Mishra et al. 2004). In addition much of the work focuses on morphology or studies conducted in containers (Soe et al. 2006) . One study compared three potential predators including dragon fly nymphs (Kumar et al. 2008) . Several other studies focused on the rates of mosquito larval consumption, morphological aspects of the mouthparts of the dragonfly, the age at which consumption was possible and the eco-friendly nature of the method.

It seems that the use of dragonfly larvae under natural conditions would require considerable efforts in maintenance. Most permanent bodies of water do not produce large numbers of mosquitoes perhaps in part due to the existence of established natural predators. The locations where large numbers of mosquito larvae would reduced by introduction of dragonfly nymphs are probably also locations where the establishment of dragonfly populations would be difficult. Temporary swales or ditches which can generate large numbers of mosquitoes periodically dry and eliminate the dragonflies. In such cases the periodic reintroduction of nymphs would be time consuming and perhaps cost prohibitive.

H.5.B. Bats. Bats are commonly suggested as an alternative method for mosquito control (Tuttle 2006). However, there are few articles in the peer-reviewed scientific literature directly addressing the ability of bats to control mosquito populations. The premise that bats can control mosquitoes is based on the assumption that bats can consume large numbers of mosquitoes if given the opportunity. Some species of bats will eat mosquitoes, however the rate of consumption is in question. The source of some of the estimates may come from the elegant work conducted by Dr. Donald Griffin and his colleagues in the 1950s (Griffin et al. 1960). Griffin demonstrated that in confined spaces a "small fraction" of bats in the genus *Myotis* when released into rooms containing large numbers (up to an initial 2000) of lab-reared mosquitoes actively fed on the mosquitoes. Based on analysis of the bat's weight gain, the authors calculate that an individual bat had consumed mosquitoes at a rate of slightly less than 10 mosquitoes/minute for the duration of the fifteen minutes testing period.

From these data, others have extrapolated to suggest that individual bats might consume up to 600 mosquitoes per hour; (10 mosquitoes/minute/bat times 60 minutes/hr = 600 mosquitoes/hour/bat). There are several concerns about this extrapolated value. First, the bats in Griffin's study were tested is an artificial environment unlike what the bat would encounter in the wild. Bats were released in rectangular tested rooms between 1000 and 3000 cubic feet. As is noted in the 1960 paper, only a small percentage (<10%) of the bats would engage in hunting behaviour. Second, the bats were only tested for approximately 15 minute periods, but the 600/hr figure is based on a continuous hour of hunting. Some reports extrapolate to longer periods of time. Third, in the laboratory experiments, the bats were not presented with of the choice of foods that they would encounter in nature. Bats were presented with either *Culex* (mosquitoes) or in other tests *Drosophila* (fruit flies).

In nature, most studies show that most insectivorous bats are opportunistic feeders with a diverse diet of insects. The composition of the diet is dependent of the geographical and temporal variation of the available food source (Agosta 2002). Some argue that bats are more likely to choose larger prey with higher caloric yield than relatively small flies such as mosquitoes. Others suggest that that since small flies and mosquitoes do not take evasive action they might be preferred over larger prey (Tuttle, 2006; Rydell et al. 2002). The composition of prey for the big brown bat (*Eptesicus fuscus*) was found to include primarily beetles, moths and caddis flies with limited numbers of mosquitoes (Agosta 2002). In another study of the little brown bat (*Myotis lucifugus*), analysis of fecal pellets indicated a very small percentage of consumed mosquitoes (Whitaker and Lawhead 1992). Of course, these results are dependent on the prevalent food source available at that time. Since bats are opportunistic feeders, they do not discriminate particular types of mosquitoes and consume all available mosquitoes including those that are not pest species. Bats also consume beneficial insects some of which might as larvae or adult themselves feed on mosquitoes. Bats, therefore, have no realistic utility in managing mosquitoes and in fact, promoting peridomestic bat populations may increase the risk for rabies exposure or other emerging viruses (Calisher et al. 2006); the vast majority of human rabies exposure in the U.S. is associated with bats.

H.5.C. Larvivorous Fish. Larvivorous fish, including the mosquitofish (*Gambusia affinis*), have been used in efforts to control mosquito populations for over 100 years (Walton 2007). Their larvivorous efficiency has been compared with other predators including copepods and dragonfly naiads (Kumar et al. 2008). The use of *Gambusia* involves the release of these fish in confined areas where large numbers of mosquito larvae flourish. Their hardiness and voracious appetite is believed to assist in the population reduction and control. Other larvivorous fish including sticklebacks and Arroyo chub (Van Dam and Walton, 2007) have been tested; however *Gambusia affinis* or *G. holbrooki* are the most employed. The effective use of larvivorous fish involves a through understanding of many biotic (population structure, size and distribution) and abiotic factors (environmental conditions).

Mosquitofish are indigenous to southeastern United States, with their northern range to southern New Jersey. They are generally not very cold hardy limiting the extent of their natural populations in the Northeast. Consequently their establishment in large numbers in the extreme northeast would be difficult and the periodic “stocking” of the fish would be required. In addition, a major concern focuses on the possible deleterious consequences of their introduction. In the right environment these fish are very hardy and likely to out-compete native species for environmental resources and consequently great care and consideration should be given to their introduction. Any use of *Gambusia* in Massachusetts would require permits from MassWildlife. The overall utility of mosquitofish is still under evaluation at a national level as is their potential impact on the environment. However, their use on an individual basis in confined areas may be useful as a supplemental control practice.

Fish are an important component in open marsh management of areas where large numbers of salt-marsh mosquitoes are observed. One component of a management scheme involves careful design and opening of channels (often pre-existing) in the marsh that can create suitable habitats for larvivorous fish. Such practices have long been used by mosquito districts as an effective biological control approach (Meredith et al 1985).

H.6. Biodiversity and health of wetlands. Mosquitoes known to have great vectorial capacity tend to exploit disturbed habitats (Spielman and Rossignol 1984). Indeed, much "emerging disease" is anthropogenic in origin. Biodiversity is likely to be reduced in disturbed sites. Mosquito density appears to be inversely related to actual or inferred loss of biodiversity

(Greenway and Chapman 2003) and WNV exposure increases with urbanization (Bradley et al. 2008). Conserving, promoting, or restoring biodiversity may be the ultimate source reduction methods, but are complex longterm objectives that could not be considered as realistic complements to or replacements for current mosquito control.

H.7. Personal protection. At the level of individuals, personal protection effectively reduces risk of mosquito-borne infection as well as nuisance mosquito bites. DEET based repellants, in particular, significantly reduce landing rates and are extremely safe, with 50 documented serious adverse events out of an estimated 8 billion doses (Fradin and Day 2002). Products containing picaridin, oil of lemon eucalyptus, and IR3535 have also demonstrated efficacy http://www.cdc.gov/ncidod/dvbid/westnile/repellentupdates.htm in repelling mosquitoes. Repellant efficacy varies from product to product and is modified by local conditions such as temperature and or exposure to rain. Toxicants such as permethrin may be applied to cotton clothing, tents, and bednets and will also effectively repel and kill biting arthropods. Personal protection should be practiced by any individual exposed to mosquitoes. However, compliance by all residents of a neighborhood or community cannot be universal even with intensive education efforts. It is logistically unlikely that personal protection could replace current mosquito control programs, which seek to improve life for large groups of individuals. Personal protection as well as peridomestic source reduction are emphasized by public education efforts that are now integral to mosquito control programs.

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[26] Copies of all references with the exception of book chapters or commercially restricted items are provided in **Appendix 11**.

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J. Qualifications of the Consultant

Sam R. Telford III ScD is an epidemiologist focusing on vector-borne infections. He received his doctorate in parasitology from the Harvard School of Public Health in 1990, and served as Lecturer in Tropical Public Health there from 1992-2002. He is currently Associate Professor in the Division of Infectious Diseases at the Tufts University Cummings School of Veterinary Medicine. Dr. Telford has contributed over 200 publications as author or coauthor, mainly on aspects of the biology of tick-transmitted infections. A recent curriculum vitae is provided in **Appendix 13**.

Alan Grant PhD is an arthropod electrophysiologist with broad training in medical entomology. He received his doctorate in 1982 from SUNY Syracuse and has been employed at the USDA, Worcester Foundation for Biomedical Research, University of Massachusetts Medical School, and American Biophysics Corporation. He is currently Visiting Scientist in the Laboratory of Public Health Entomology at the Harvard School of Public Health. His research focuses on the sensory physiology of mosquitoes.

K. List of Appendices

Appendix 1. Certificate of the Secretary of Energy and Environmental Affairs for the

Commonwealth of Massachusetts on the Generic Environmental Impact Review Update E0EEA #5027, issued January 16, 2009

Appendix 2. Comments on EOEEA #5027 received after October 24, 2008 and Response to Comments

Appendix 3. Data files provided by MCPs.

Appendix 4. Product labels and material safety data sheets (MSDS)

Appendix 5. Adult mosquito control intervention parameters: scientific data to support the effectiveness of spraying.

Appendix 6. Education and outreach examples.

Appendix 7. Addendum to the Freshwater BMP: Mechanized wetland management activity post-monitoring guidelines

Appendix 8. Customer satisfaction survey, Central Mass MCP

Appendix 9. Examples of Research conducted by MCPs

Appendix 10. MEPA filings; plans, policies, analyses, and management practices issued by SRMCB since the 1st GEIR Update; includes annual reports for 2008 from each MCP.

Appendix 11. Literature Review of alternatives to current mosquito control practices

Appendix 12. Copies of Literature Cited

Appendix 13. Curriculum vitae of Consultants.