State of Massachusetts

Generic Environmental Impact Report on Mosquito Control

Executive Summary

I. Introduction

A Generic Environmental Impact Report (GEIR), covering mosquito control activities within the State of Massachusetts, was mandated under the provision of Massachusetts General Laws Chapter 30A Section 61 by the Massachusetts Environmental Policy Act (MEPA) Regulation 301 CMR 10.32(5)(b) adopted on January 25, 1979. The State Reclamation and Mosquito Control Board (SRMCB), the state agency that oversees all local and regional mosquito control programs in Massachusetts, administers the GEIR. The SRMCB consists of one representative each from the Departments of Environmental Management, Environmental Protection, and Food and Agriculture. The latter member presently serves as the Chairman of the Board.

This GEIR serves five purposes:

1. It provides a historic summary of all public activities in Massachusetts related to mosquito control, including an account of how mosquito control in Massachusetts has rapidly evolved over the past ten years.
2. It describes and quantifies Massachusetts mosquito problems and assesses the effectiveness of past and current control programs.
3. It assesses the real and potential environmental impacts of past and current control practices and describes and evaluates alternative strategies.
4. It gives an IPM framework for mosquito control in Massachusetts and provides a series of operational standards for mosquito control practices.
5. It makes recommendations relative to the future organization and practice of mosquito control in Massachusetts.

II. History, Organization and Practice Of Mosquito Control In Massachusetts

A. Legislation and Regulation

1. State Laws

The first Act of major importance is Chapter 252 of the Massachusetts General Laws (MGL), which establishes the State Reclamation and Mosquito Control Board (SRMCB) and procedures for creating local control projects. As now amended, 252 includes the important earlier provisions of Chapters 199 and 699 of the Acts of 1960. The word improvement (of wetlands) as frequently used in the narrative for this Act is misleading. Modification or alteration would have been a more appropriate and objective term to describe wetland drainage and filling activities.

The second Act is the Wetlands Protection Act (Chapter 131 of MGL) which regulates activities in the aquatic and brackish habitats where most mosquitoes breed. However, organized mosquito control is generally exempt from the provisions of this State Law. Hence, the Federal Clean Water Act as administered by the U. S. Corps of Engineers, is the principal regulating mechanism for mosquito-control alterations in wetlands. Regardless of the general exemption, mosquito control is not exempt from checking for the presence of rare and endangered species through the Massachusetts Natural Heritage Atlas, which lists estimated habitat maps for all rare and endangered species as developed by the Natural Heritage Endangered Species Program (NHESP).

The third Act which influences mosquito control in the Endangered Species Act (Chapter 131A of MGL) which prohibits the “taking” of rare and endangered species. It also protects “significant habitats,’ requiring a permit request for any work done in such areas.

The fourth Act of importance to mosquito control activities is the Pesticide Control Act (Chapter 132B of MGL) which regulates pesticide use by mosquito control practitioners.

Three additional Acts have the potential to impact mosquito control. M.G.L., Chap. 91. Sections 1-63 -- Waterways does not deal specifically with mosquito control but it does cover variety of activities associated with wetlands. Mosquito control is specifically exempted from the provisions of Sections 19A, 59 and 59A of this law but not from other provisions. M.G.L., Chapter 40. Section 5 - Boards of Health and Supervision, contains clauses that address the issue of appropriating money at the municipal level for mosquito abatement. M.G.L., Chapter 132A. Sections 13-16, 18 -- Ocean and Coastal Sanctuaries Act, Section 14, is designed to is to protect designated ocean sanctuary from any "...exploitation, development, or activity that would seriously alter or otherwise endanger the ecology or the appearance of the ocean, the seabed, or the subsoil (of the sanctuaries), or the Cape Cod National Seashore." Mosquito control does not take place in these sanctuaries.

2. Federal Laws

Federal laws which directly impact on mosquito control activities are Sections 401 and 404 of the Clean Water Act and the Endangered Species Act. All other federal restrictions governing wetlands and pesticides are covered by Massachusetts laws which impose restrictions and requirements that are equal to or greater than those in comparable federal law. The exception in the case of Section 404 arises because the state laws governing the ditching of wetlands exempt mosquito control but the Federal Clean Water Act does not.

Section 401 (Clean Water Act: Water Quality Certification) requires applicants wishing to discharge dredged or fill materials to obtain a certification or waiver from their state water pollution control agency (Massachusetts Bureau of Resource Protection, Division of Wetlands and Waterways). The U. S. Army Corps of Engineers will not permit a mosquito-control project that does not have a water quality certification.

Section 404 of the Clean Water Act (1972), calls for a system of permitting to be carried out by the U.S. Army Corps of Engineers with a review of al! permit applications by appropriate state and federal agencies. The activities that involve mosquito control which require a permit under Section 404 are cutting or clearing new mosquito ditches in tidal areas below mean high water and/or placing material excavated from existing or new ditches on salt marshes or freshwater wetlands.

The Endangered Species Act is designed to protect threatened and endangered species as listed on the Natural Heritage Atlas. To date, several programs have had to modify their control effort to take into account endangered species.

B. Current Mosquito Control Programs in Massachusetts

1. Formal Mosquito Control Projects

Of the 351 Towns in Massachusetts, 157 (or 44.7%) currently belong to the 9 organized mosquito control projects. Each project is managed by a superintendent who is hired and supervised by a Board of Commissioners representing the towns included in the project. Board members are appointed by the Board of Reclamation for designated terms (usually 3-5 years). Boards generally meet once or twice monthly to authorize major expenditures and to review policy and program progress.

The SRMCB is made up of three members, one each from the Departments of Food and Agriculture, Environmental Management and Environmental Protection, and exercises responsibility over all 9 projects. All projects have a Board of Commissioners appointed by the SRMCB. They represent the various towns within each project and exercise general control over the project.

The Nine Mosquito Control Projects of Massachusetts are Berkshire County, Bristol County, Cape Cod, Central Massachusetts, East Middlesex County, Norfolk County, Plymouth County and Suffolk County Mosquito Control Projects and the North East Massachusetts Mosquito Control and Wetlands Management District (formerly Essex County MCP). Nantucket conducts saltmarsh mosquito control including larviciding and open marsh water management.

2. Other State Agencies

The State Division of Forests and Parks discontinued its own mosquito control program in. The North East Massachusetts Mosquito Control and Wetlands Restoration District (NEMMCWRD) adulticides Salisbury Beach State Park and Bradley Palmer State Park in Hamilton as the need arises.

The Massachusetts DPH is responsible for surveillance for EEE Virus, risk assessment, public information and education on EEE disease, as well as providing advice to the State Reclamation and Mosquito Control Board on appropriate risk management for EEE. DPH is also responsible for recommendations for wide area aerial vector control interventions in the event of an EEE Public Health Emergency.

3. Federal Property

No mosquito control is carried out by the U.S. Department of Interior on any government-owned land in Massachusetts. The Cape Cod National Seashore is perhaps the U.S. Park Service property with the most significant mosquito populations. Park Service biologists have conducted their own studies on the environmental impact of Cape Cod mosquito control activities (Portnoy 1983, 1984a, 1984b) in adjacent estuaries and have lobbied against certain ditch cleaning practices on environmental grounds.

The East Middlesex MCP has been controlling mosquitoes in Great Meadows National Wildlife Refuge since 1987. Annual aerial Bti applications targeted against spring *Aedes* species began in 1987 and applications to control *Aedes vexans* began in 1990. The National Park Service reservation area (Paul Revere's Ride) in East Middlesex County has been declared off limits to any mosquito control activity (by East Middlesex MC project) except for ditch cleaning.

The NEMMCWRD has completed OMWM projects on the Parker River Wildlife Refuge.

C. Overview of Mosquito Control Practices in Massachusetts

Development and tourism along the Massachusetts coast is predicated on an ability to control the hoards of saltmarsh mosquitoes. Massive hand-ditching projects in East Coast marshes that took place during the WPA programs of the great depression. These ditching schemes, while quite effective in reducing saltmarsh mosquitoes, were engineered to make work rather than for optimum biological efficiency.

Early saltmarsh mosquito control projects, such as the one on Cape Cod in the 1930's, were organized prior to the availability of synthetic pesticides following World War II and these projects expanded and maintained the WPA-dug ditch system as their main strategy for mosquito control. After DDT, BHC, and other organochlorine pesticides became available, they were used to both supplement larval control and, for the first time, to conduct residual spraying for adults. Aerial application of these pesticides became commonplace in the 1950's and early 60's. The commercial mosquito control oil, Flit ML0, was introduced and widely used during the 70's.

Chemical control in freshwater marshes followed a similar pattern to that in salt marshes. Treatment of catch basins, first with oils followed by organochlorines and organophosphates, dates back to the beginning of most Massachusetts projects.

Physical control was limited to drainage maintenance and expansion in both salt marshes and freshwater areas. Biological control was not conducted.

By the early 1980s, concerns over pesticide use and wetlands loss began to encroach on mosquito control. Grid ditching for larvae and malathion for adults was no longer a desirable one-two punch. Control trends during the eighties and early nineties included: changing from traditional chemicals, such as Abate and Flit MLO, to Bti and methoprene for larval control, changing from malathion to permethrin or resmethrin for adult control, and changing from open tidal ditching to open marsh water management for saltmarsh mosquito control.

Source reduction remained a mainstay of the projects during this time period. Coastal communities shifted away from ditch maintenance towards open marsh water management. An emerging difficulty for control programs is the rise in wet basins mandated by stormwater runoff regulations.

The evaluation of control effectiveness by projects remained a combination of public complaints, adult counts, larval counts, and cases of human disease.

Chemical control, including *Bacillus* products and IGRs, and source reduction, including open marsh water management, now dominate mosquito control in Massachusetts. Aerial applications of larvicide have been used by several programs and are increasing. Biological control has not been emphasized except to the extent that OMWM creates conditions under which biological control operates. Public education is a minor component of most programs.

Saltmarsh mosquitoes are the primary target of coastal programs, whereas inland programs target spring-brood and summer-reflood *Aedes*. *Coquillettidea perturbans* is restricted by larval habitat to areas near cattail marshes but is a big problem in those areas. It complicates control efforts because controlling the larval stage with methoprene is expensive and adulticiding provides only short-term control.

Vector mosquitoes are not the primary targets of Massachusetts control programs, though projects can respond to requests for aid from DPH in times of EEE emergencies. *Culiseta melanura* larval populations may be incidentally reduced by treatment programs that target swamp areas.

At present, policy issues revolve around wetlands protection, water quality preservation, and endangered species. A chronic source of discussion is mosquito control's exemption from many of the state-level wetlands protection acts, making the Federal Section 401 Water Quality Certification (administered at the state level) and the state and federal Endangered Species Acts the primary means of "controlling" source-reduction work. Stormwater runoff regulations have increased the number of wet basins (retention, wet detention) in many areas, on occasion creating breeding habitat

The EEE outbreak in 1990 highlighted a need for stronger DPH policies regarding emergency mosquito control. As a result, the Massachusetts Department of Public Health published "Vector Control Plan to Prevent Eastern (Equine) Encephalitis" (August 7, 1991) and implemented an extensive Public Education Program in 1991.

The combination of large, affluent human population (both permanent residents and visitors) and prolific pest mosquito populations near Massachusetts coastal marshes suggests that the public may always demand control programs to deal with this problem.

Open Marsh Water Management (OMWM) projects now underway in Essex, Norfolk, and Plymouth counties are being expanded to include essentially all problem marshes in those counties. The trend to convert grid-ditch systems to OMWM is likely to continue.

There are certain salt marshes where old ditches are effectively controlling mosquito production and perhaps where new OMWM activities might actually disrupt the marsh more than maintaining the status quo. Thus, OMWM plans should not be automatically prescribed for every saltmarsh without first examining this issue. Larviciding is still carried out in salt marshes.

Inadequate budgets, the inability to conduct more source reduction work and a lack of applied research into more environmentally sound mosquito-control practices continue to restrict the actions and effectiveness of mosquito control programs in Massachusetts.

III. Current Abatement Strategies and Their Impacts

A. Chemical Control

Twenty-six different insecticide formulation distributed among fifteen product lines were used for mosquito control in Massachusetts between 1993 and 1995 (Table 1). Eight of these formulations used Bti as the active ingredient, five were methoprene-based, three were resmethrin-based, two each were pyrethin-based or malathion-based, and there were one each of temephos, isoctedecanol, and mineral oil. Of these, Acrobe (Bti) and Vectobac AS (replaced by 12AS) are no longer produced. Arosurf-MSF (Isoctadecanol) was off the market for several years but is now available under the name Agnique MMF. Abate 4E was not used in either 1994 or 1995 and both the Malathion 10EC and the Resmethrin product (EPA reg. # 4-339-53853) were used in small amounts only

Of the insecticides used, all of the larvicides were classed as Category IV (Category I is the most toxic, Category IV the least) materials by EPA. Bonide Mosquito Larvicide, available but not used, is border line between Category III and IV. VectoLex CG, a new *Bacillus sphaericus* product, is Category IV. All adulticides are in Category III, with permethrin and resmethrin having essentially replaced malathion.

Chemical impacts include acute, direct impacts to target and non-target organisms, and chronic or indirect effects to target and non-target organisms. In general, acute toxicity effects are generally easiest to measure and avoid, particularly when the organism is large and the effect is death. However, less visible acute toxicity, such as

Table 1. Chemicals used in Massachusetts mosquito control, 1993 through 1995

Trade Name	EPA Registration Number	Active Ingredient(s)	% Active Ingredient	Toxicity Class	Other Warning Statements
LARVICIDES					
Abate 4E	241-132	Temephos	43	IV	
Acrobe[a]	62637-1-241	Bti[b]		IV	
Arosurf-MSF[c]	42943-8	Isooctadecanol	100	III	
Altosid					
Briquets	2724-375-64833	Methoprene	7.9	IV	
XR Briquets	2724-421-64833	Methoprene	1.8	IV	
Pellets	2724-448-64833	Methoprene	4.0	IV	
Bactimos					
Briquets	43382-3	Bti	10	IV	
Granules	37100-43-2217	Bti	0.2	IV	
Pellets	37100-42-2217	Bti	0.4	IV	
GB-1111	8898-16	Petroleum Hydrocarbons			
GB-1356	8898-16				
Teknar HP-D	2724-365-64833	Bti	0.8	IV	
Vectobac					
AS	275-52	Bti		IV	
12AS	275-66	Bti	1.2	IV	
Granular	275-50	Bti	0.2	IV	
ADULTICIDES					
Malathion 8EC	34704-119	Malathion	8	III	
Permanone 10EC	4816-688	Permethrin	10	III	
Permanone 31-66	4816-740	Permethrin	31	III	
Resmethrin	4-339-53853	Resmethrin		III	
Scourge 4+12	432-716	Resmethrin	4	III	RESTRICTED USE
		PBO	12		CLASSIFICATION
Scourge 18+54	432-667	Resmethrin	18	III	Due to acute fish toxicity
		PBO	54		Retail sale to and use only by Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicators Certificate
MATERIALS REGISTERED BUT NOT USED - LARVICIDES					
Altosid					
Liquid	2724-392-64833	Methoprene	5	IV	
Liquid Con	2724-446-64833	Methoprene	20	IV	
Bonide Mosquito					
Larvicide	4-195	Mineral Oil	98	III-IV	
VectoLex CG	275-77	*B. sphaericus*	50[d]	IV	
MATERIALS REGISTERED BUT NOT USED - ADULTICIDE					
Fyfanon ULV	4787-8	Malathion	95	III	

[a]No longer marketed
[b]*Bacillus thuringiensis* var. *israelensis*
[c]Now marketed as Agnique MMF

methoprene toxicity to Chironomid larvae in duck-breeding habitat (SPRP 1996), may cause harm in the short term, and, since it often goes unnoticed, may be harmful in the long run as well. Mosquito Control Programs have limited, but not removed, the threat of acute impacts to non-targets by using pesticides that are more specific to the target, less toxic to non-targets, and/or have a shorter persistence in the environment. The amount of pesticide used, as in the case of ultra-low-volume sprays versus mist sprays, has also been reduced.

Chronic effects that may occur include the long-term effect of the chemical on targets (development of resistance to the chemical) and non-targets (reduced reproductive success), and long-term effects caused by a change in the ecosystem brought about by removal of the target organism. The current assumption is that the mosquitoes controlled are those which have escaped the food web and which, therefore, may be eliminated without undue risk to the food web itself. That mosquitoes are remarkably productive cannot be denied. That removing millions of larvae from the food web of a salt marsh by the application of Bti has no effect on that ecosystem deserves additional study, as does the role of mosquitoes in the ecosystem, and the effect of mosquito control on that ecosystem.

Control personnel should take care to avoid chemical applications where mosquito larvae are not present or are present in very small numbers, should use control measures that do not harm existing predator complexes, and should limit control to areas where control is necessary, allowing natural cycles to continue in areas where human activity and the risk of disease transmission is slight. One argument made in favor of Altosid is that it does not kill the young larvae, leaving them available as food for the existing predator complex.

Barring the discovery of new materials, both adulticiding and larviciding are presently be conducted with the least risk imposing materials available for the foreseeable future. Advances in reducing the risk of chemical use must therefore come from improved targeting and increased use of water management and/or biological control techniques.

B. Biological Control.

Biological control includes attacks on the pest species by other species and manipulation of the pest species itself. Only the former has been used in Massachusetts. Note that, for the purposes of this GEIR, Bti, *Bacillus sphaericus* and methoprene are classified as chemical controls and open marsh water management is classified as a physical control. A case can be made for classifying each of these strategies as a type of biological control.

Biological control agents are grouped into three categories: predators, parasites and pathogens. Predators include both vertebrates and invertebrates and may attack both adult and immature stages of mosquitoes. In general, biological control is much more feasible in managing permanent water mosquitoes than temporary water forms.

There are three basic strategies for utilizing all biological control agents: 1) increasing existing natural enemy populations by habitat improvement, 2) one-time introduction of sustainable exotic agents from other regions or habitats, and 3) augmentation of natural or exotic enemy populations by repeatedly releasing non-sustainable, lab-reared (or field collected) organisms. To date only the first, increasing fish habitat through OMWM, has been used in Massachusetts. Bti could arguably be classified as a biological control agent but its application technique and mode of action functioning as a stomach poison more closely resemble a pesticide than a biological control agent *per se*. *Bacillus sphaericus* may more closely fit the model of repeatedly releasing non-sustainable lab-reared organisms as there is evidence to suggest that it recycles within the environment.

There are important reasons why biocontrol is not more widely used against mosquitoes. First, the differences in biology of the various species of mosquitoes make it unlikely that any one control agent will operate across a wide range of species. Second, mosquito breeding is wide spread, making it difficult for a biological control agent to find, or be placed in, all breeding areas. Third, predators such as bats and purple martins, may eat mosquitoes but prefer to eat other, larger insects. Finally, there is a high cost associated with sustained releases of a biological control agent and there are not, at this time, control agents available that require a single, or a few, releases to become established.

The impacts on biological control have not received much attention because biological control has not been exercised to any great degree in Massachusetts. However, one of the primary reasons *Gambusia* are not being used in Massachusetts is the fear that they might displace native species of fish, thus altering the natural biota, not by predation but by competition for the same resource.

C. Habitat Modification (Physical Control)

1. Salt Marshes. Open Marsh Water Management was originally developed for New Jersey salt marshes (Ferrigno 1970, Ferrigno and Jobbins 1968, Ferrigno et al. 1969), this strategy basically attempts to overcome the limitations of ditching by incorporating other water management strategies. Reservoirs (which permanently hold water and sustain larvivorous fish) are created in selected tidal pools or large shallow pans and are connected via small shallow ditches to surrounding mosquito breeding depressions. This customized

approach to marsh management represents the least deleterious and most efficient non-pesticidal method for controlling saltmarsh mosquitoes.

New England coastal wetlands have been heavily impacted by man (Shisler 1990). However, evidence concerning the negative impact of saltmarsh ditch maintenance activity is mixed. The principal concern is with disposal of the spoil on the marsh and the alleged invasion of upland plants that can occur with even slight elevation increases (i.e. 1-2 inches). OMWM effects are apparently limited (Wolfe 1996) but all alterations must be designed so that raised patches of marsh elder and other boundary plants are not created.

2. Freshwater Wetlands (exclusive of Vernal Pools). Palustrine wetlands, including emergent, scrub-shrub and forested wetlands, are the dominant system in which Massachusetts freshwater physical control take place. Typically, this work consists of maintaining existing ditching designed to remove standing water from the wetland, thereby reducing mosquito-breeding habitat. For most MCPs, this type of work (source reduction) makes up a large percentage of their control effort. Though reducing standing water certainly reduces mosquito breeding, there has been little research concerning the overall effects of these alterations on the modified wetland. Ditch systems can become problems in their own right, producing mosquitoes if left unmaintained. Most of these systems were never designed specifically for mosquito control and their other, primary function, such as removing runoff from large parking lots, may cause considerable damage to the ecosystem, leaving the MCP to clean up, or at least deal with, someone else's mess.

The majority of drainage systems currently maintained by MCPs were not initially constructed for mosquito control and the effort of MCPs today is almost entirely restricted to removing blockages to existing flows, rather than enlarging or straightening channels to increase flow. Road sand and yard waste represent two of the most common obstructions MCPs are called upon to remove from existing drainage networks. New developments also can cause dramatic changes in the sediment load in streams, despite regulations designed to prevent such problems. Road sand, yard waste and increased sediment load from development can all have impacts on a stream that are as greater or greater than regular ditch maintenance. Because MCPs are often involved in removing manmade sediments from streams, a system under appropriate ditch maintenance may function more closely to a natural system than one in which manmade wastes are allowed to accumulate unabated.

The three broad categories of wetlands alteration are outright loss, changes in the abiotic system and changes in the biotic community. Filling and/or draining wetlands to convert them to upland is a mosquito-control practice that has been all but eliminated in Massachusetts. There is no indication that MCPs are intentionally reducing wetland acreage in order to control mosquitoes. However, the fact that the wetlands boundary remains essentially unmoved by a mosquito-control alteration does not mean that changes to the ecosystem have not occurred.

Changes in the abiotic system and biotic community are deeply intertwined, though physical control most often causes abiotic changes which then cause biotic changes. For channels changes in flow rates, microhabitats, sediment load, sedimentation, and groundwater interactions can all occur. For wetlands (outside of channels) changes can include lost water-storage capacity, increased sedimentation and pollutant load, changes in water depth, and changes in groundwater hydrology.

When a stream is altered to improve water flow for the purpose of removing standing water, either within the stream or from adjacent wetlands, a number of changes may take place. By definition, improving water flow increases runoff. This, in turn, may decrease the surface-water storage capacity of the wetland system and decrease the capability of the wetland to retain load (suspended solids). This may increase the load of the water moving through the stream (Brown 1988). Increasing runoff into a given stream tends also to increase erosion, which further increases load (Williams & Feltmantle 1992). Not only may total flow be increased, but alteration tends to increase peak flow, which is associated with reductions in faunal diversity (Hynes 1972). Increased peak flow may also lead to faster drying in intermittent streams.

Maintenance for the purpose of reducing mosquito breeding also includes removing obstructions within streams. Tree branches and fallen trees are a particularly important part of the stream environment, providing food, living space, concealment from predators, protection from abiotic conditions and emergence sites (Ward 1992). Removing these obstructions diminishes the variability of the stream ecosystem.

The hyporheic zone, the interstitial space between the substrate particles in a stream bed, is an important part of the habitat for many stream species (Williams & Feltmantle 1992). Excessive drying can reduce the viability of the hyporheic zone.

Sedimentation, both within stream beds and in wetlands into which streams flow, is a problem because it can alter the stream bed composition, thereby altering the fauna, and can clog interstitial spaces, thereby reducing the hyporheic zone and/or reducing groundwater recharge. Sediments can also increase exposure to pollutants as they provide additional sites for pollutant binding while suspended, and then carry the pollutants to the benthic fauna. Sedimentation, however, results most often from sources other than mosquito-control activities, and it is the primary cause of maintenance work.

When new channels are constructed, they are typically designed to change standing-water wetlands to soil-saturated wetlands (New Jersey DEP 1997). Though this reduces mosquito breeding it can also adversely affect other organisms that require standing water for periods other than peak flow.

Increased drainage also has an effect on groundwater. Precipitation and inflow determine the amount of water initially available to a wetland for ground water recharge (Todd 1972). Increasing the amount of water removed from the wetland and/or stream prior to percolation downwards may decrease groundwater recharge.

What is most needed is a comprehensive understanding of the true ecological costs of physical alterations for mosquito control. This is particularly important because, although the environmental effects of pesticides receive the lion's share of concern, it is likely that the long-term effects of physical controls have a more profound effect on the environment than does pesticide use (Buchsbaum 1994). This may be especially true today with the switch from broad-spectrum, more-persistent pesticides to methoprene and Bti.

3. Vernal Pools. Vernal pools form in contained depressions in which water stands for a period of several months, generally from mid- to late winter through the spring. Water either comes in the form of snow melt or spring precipitation or can be a result of a rising water table. Some pools dry down within two or three months, others may only dry when the water table is lower than normal, resulting in a pool that is semi-permanent. Regardless, a key feature of vernal pools is that they undergo periods of dry down. Vernal pools may have permanent inlets but do not have permanent outlets (Kenney 1995). There are numerous obligate species for vernal pools, the most visible of which include fairy shrimp, the wood frog (*Rana sylvatica*) and several species of salamander (*Ambystoma* spp.).

Mosquito species such as *Ae. canadensis* and *Ae. excrucians* also use vernal pools for breeding. From a control perspective, vernal pools are important because, due to increasing protection, vernal pool habitat is often left undeveloped while the land adjacent to the pool is built up. As a result, many new developments surround known breeding sites. Regardless of the wisdom of developing so close to vernal pools, mosquito-control personnel are charged with controlling the mosquitoes coming from the pool.

4. Rare and Endangered Species. Operating under the assumption that it is rare and endangered species which are most likely to be lost from a wetlands system first, then reductions in habitat

diversity, alterations from the natural state, and frequent disturbances will all work against these species. Channelization of streams reduces diversity by removing obstructions, straightening the channel and increasing flood levels. Wetlands changed from standing-water to saturated-soil regimes have been drastically changed from their natural state. Maintenance is ongoing, as is the disturbance it causes.

However, to what extent does mosquito control contribute to the these problems? First, Massachusetts MCPs do not channelize streams, as their certification manual calls for following the existing meanders. Second, MCPs work neither in historically undisturbed, nor currently undisturbed streams. There is good reason to argue that there is no specific "natural" state that can be assigned a ditch dug by man and intermittently filled with road sand and grass clippings. Even with natural streams, the "natural" habitat in which they flow has long been altered and continues to be altered.

The Natural Heritage and Endangered Species Program (NHESP) was created in order to conserve and protect those plants and animals not hunted, fished, trapped or commercially harvested in the state. The program's highest priority is to inventory rare and endangered species and to develop conservation plans through research, management and habitat protection for those species

The NHESP also reviews proposed alterations to wetlands habitats under the Wetlands Protection Act (M.G.L. c. 131, s. 40 and regulations 310 CMR 10.00). NHESP has produced a series of estimated habitat maps for rare and endangered species (Massachusetts Natural Heritage Atlas) which proponents of a given alteration are required to check. Should a project fall within an estimated habitat, NHESP will then determine if the area to be altered is actual wetland habitat for a state-listed species. The results of the NHESP determination are given to the inquiring MCP.

In Massachusetts, the species that have caused modifications in mosquito control practices are the Blue-spotted salamander (*Ambystoma laterale*), Mystic Valley amphipod (*Crangonyx aberrans*), and banded bog skimmer (*Williamsonia lintneri*). In addition, ditch maintenance in vernal pond areas has been curtailed to protect this type of habitat. Other animals for which concerns have been raised are the yellow-spotted turtle and osprey.

Under the current system mosquito-control maintenance activities are exempt from the Massachusetts Wetland Protection Act, leaving the federal 401 Water Quality Certification Act and both the Massachusetts and Federal Endangered Species Acts as a method for regulating maintenance. Unfortunately, water quality, while important, does not address the issue of changing habitat and the presence or absence of a rare or endangered species has little to do with the merits of a given drainage project. Again, a more comprehensive understanding of the true ecological effects of mosquito control is required to better determine the cost/benefit ratio for different types of mosquito control, including their effect on rare and endangered species.

Physical control by water management may increase predation, as in OMWM, or may eliminate predator and prey as when wetlands are drained to soil saturation. Mosquito breeding must be thoroughly documented before new work is done. Because disturbances may displace some species, and because predator species tend to rebound more slowly than their prey, maintenance work should be conducted only when necessary.

D. No Program

Many communities in Massachusetts have chosen to forego mosquito control. These town are usually outside of the enzootic EEE zone so the risk of human diseases transmitted by mosquitoes is viewed as practically nil by these communities. In addition, they are not located near salt marshes and their attendant pest mosquito problems. The mid-section of Massachusetts, where most no-control communities occur, also has a more rural character, less wetland , lower human populations, and a lower mean family income than most eastern areas with organized MCPs.

In addition to risk-benefit considerations, other criteria for weighing the control/no control option are 1) the feasibility of successfully reducing annoyance below the human annoyance threshold, and 2) the adequacy of community resources for reducing annoyance to acceptable levels.

It is difficult to measure the impact of choosing the no control option. The example of towns that have left, and later rejoined, mosquito control projects is perhaps the only available basis for estimating public opinion concerning such impact. However, no documentation of annoyance levels, cases of disease, recreational dollars spent, etc., was ever attempted in these towns when they had mosquito control versus when they did not.

The number of towns in MCPs declined in the late eighty's. Economic factors, not environmental concerns, were the dominant reason given for withdrawal. This trend has reversed itself significantly in the last several years. The 1990 EEE problem is probably one reason, coupled with the fact that several coastal programs tried the no-control option and found mosquito numbers rose quickly.

IV. IPM as it Relates to Mosquito Control.

A. Definition of IPM

At its most basic IPM is:

A system designed to reduce the negative impact of a pest species to an acceptable level while avoiding unnecessary additional problems (Virginia Cooperative Extension Service 1987).

For mosquito control in general the negative impacts of mosquitoes are reduction in outdoor use, particularly recreational, and disease transmission. These negative impacts are all ongoing in Massachusetts. Problems that have developed in the past are loss/degradation of valuable habitat, exposure of non-target organisms to pesticides, creation of new, sometimes worse, breeding habitat, and resistance of mosquitoes to pesticides in use. Other than exposure of non-targets to pesticides (unavoidable) none of these problems have been documented in Massachusetts.

Before an IPM program can be put in place, a strong organization must be in place. The organization must be adequately funded, adequately trained and provided with the materials to do the job correctly. At a minimum expertise in mosquito biology, wetlands ecology, and program administration are required.

Adequate staffing and resources are only the first steps in creating an IPM program. The main step is in creating the analytical process whereby control decisions are made, evaluated and modified. This process can be divided into four steps: 1) Surveillance and Monitoring, 2) establishing Thresholds for Action, 3) Prevention and Control, and 4) Evaluation.

1. Surveillance and Monitoring. For mosquitoes, adult populations are monitored for their direct impact on people whereas larval populations are monitored for their potential impact after they emerge as adults. For adult populations, monitoring is used to determine if adulticiding is required and to identify the species of mosquito in a given area so that future larval control efforts can be directed at the appropriate breeding sites. Larval populations are monitored to determine if larviciding is required and/or if physical or biological controls are working.

The habitats in which breeding occurs or in which the adult mosquitoes are most numerous must also be identified. Wetlands should be mapped as should drainage basins.

A third component of monitoring is to classify the area in which control is to take place by human usage. Unless funding is not a constraint, the goal of surveillance and monitoring should be to produce a site list prioritized by the level of mosquito breeding and its proximity to humans.

2. Establishing Thresholds for Action. The goal of IPM is to keep pest levels below the

Economic Injury Level (EIL). This is the level where the economic loss from pest damage exceeds the cost of control. In mosquito control, this is the Human Annoyance (or Disease) Threshold (HAT) and represents the highest biting density (or Disease Incidence) that most citizens in a community find tolerable. Intolerance is usually exemplified by people moving indoors, putting on repellent, leaving a campground etc.. HAT is generally the biting level above which most people prefer to pay to have the level reduced than put up with the annoyance. This level will vary from community to community and may be influenced by the species biting (Sjogren, 1977), the time of day when annoyance occurs, and the duration of the period when HAT is exceeded.

The choice of control measures to use, and the extent to which a given control measure is used, is determined by the pest species and population, the environment in which the pest population is located, and human factors expressed in political and economic terms. Determining which control options are available and how much funding will be allocated to each, coupled with an understanding of the pest population, should allow action thresholds to be created.

3. Prevention and Control. Prevention refers to maintaining a pest population below the action threshold for control, whereas control refers to bringing a pest population back under the threshold for control. Source reduction is the primary prevention technique for mosquito control in that it directly reduces the area in which mosquitoes can breed. Maintaining water flow through drainage networks is the primary freshwater mosquito control technique while ditching used to be the primary prevention in salt marshes. Programs that do not stress source reduction cannot make long-term reductions in mosquito populations.

Public education is a second vital component of prevention. An educated public should be more willing to cooperate in eliminating man-made breeding habitats, should better understand the trade-offs between the various available control techniques, and should be more willing to fund more expensive approaches if the expense can be justified by a better long-term benefit.

Control, in the sense of killing mosquitoes, is dominated by chemical use for adult mosquito control. For larvae a combination of chemical control and OMWM (biological/physical control) is used.

Thresholds are vital to the control process because only through thresholds can a rational response be made to unusual circumstances. A quality IPM program cannot “fail” in the strict sense because it has control techniques available for each step in pest population increase (or, in the case of a disease threat, each increase in the risk of contracting the disease).

4. Evaluation. Each control step is evaluated for efficacy and future actions modified to improve control or reduce negative impacts. Field evaluation will generally use the same monitoring techniques described above and the important criteria will be changes in the mosquito population and/or environment. Over time, a steady state should develop where realistic thresholds trigger effective responses.

B. IPM for Mosquitoes as it is Currently Practiced in Massachusetts.

The strategy of IPM as developed for agricultural ecosystems is an ecologically-based concept (Axtell 1979). It has yet to be fully applied to mosquito management programs. IPM is a strategy for managing insect populations not a method for controlling them. It is more than integrated control which is simply the combining of several control methods. Mosquito control has a long history of integrating different control methods.

The general feeling among most MC practitioners is that any significant larval population within flight range of residential areas will probably result in some human annoyance and therefore should be controlled. No Project in Massachusetts has undertaken such an effort.

Although many MC programs regularly monitor adult population levels (with light traps and landing counts) they do it to evaluate larval control effectiveness and the need for adulticiding; not to determine when immediate larval control is needed as in the case of agricultural IPM programs. However, light trap counts, landing rates and complaint calls are used to create a general picture of the need for mosquito control and projects with long-term experience develop larviciding plans based on this historical data.

There is no study to date of the costs and benefits of Massachusetts mosquito control programs. There is good reason to believe, even if such studies were done, that the results would reflect local, current thought, as opposed to some underlying “true” cost/benefit for mosquito control. Regardless of the underlying variability of any cost/benefit analysis, working towards an understanding of the costs and benefits of mosquito control is desirable. The following information would aid in such work:

1) Establish human annoyance thresholds (HAT)
2) Document how human activity patterns relate to HAT and economic factors
3) Determine cost/benefit analysis of control (willingness to pay)
4) Correlate HAT with a standard non-biting sampling method (e.g. light trap)
5) Correlate densities of immatures with future levels of biting annoyance.

The cost/benefit of various control options (e.g., permanent vs. temporary control) also has been evaluated

(Ofiara & Allison 1986a, 1986b) but this should not be confused with the cost/benefit of control programs.

One major advance already underway is vastly improved mapping through Geographic Information Systems (GIS). GIS wetlands mapping can both aid mosquito control agencies in determining control priorities but can be used by mosquito control agencies to integrate their work with other land-use agencies (Guthe 1993). Very detailed maps can also be made when planning water management projects (Gettman 1995).

Overall, Massachusetts mosquito-control IPM strengths include, strong control programs, good pre-treatment monitoring, the availability of and willingness to use least-toxic materials and a willingness of existing control programs to try new control strategies. Weaknesses include a lack of funds for research into new strategies, a lack of funds to implement new strategies and a lack of basic ecological data on the effects of control strategies in use or being planned. A final wildcard is EEE which dramatically increases the stakes when attempting to determine the correct response. DPH has developed a monitoring program that should bring EEE into the IPM framework.

V. Standards For Mosquito Control

A. Standards for Monitoring and Control. Pesticide applications in an IPM program require monitoring insect populations and comparing data with pre-established thresholds for treatment. In addition, post-treatment evaluation is required to ensure the treatment worked as planned and did not have unintended side-effects.

1. Larval Populations: The primary technique for larval population counts is the dip count. It is hard to standardize dipping technique but, for the purposes of this document, it is assumed that dips are taken in undisturbed pools (the field person is aware that disturbing the water and/or casting a shadow over the water will cause mosquitoes to dive, thereby lowering counts) known by the field personnel to be typical of the breeding area being monitored. For large-scale work, dipping will be done at permanent, marked (or easily located) dip stations. For small sites such as drainage basins and woodland pools, dips will be taken at random throughout the site. Up to twenty dips per site will be taken unless the count for treatment and/or water management is exceeded with a smaller number of dips. Specifics for various types of work are given in Table 2.

Table 2. Specifics for monitoring larval (& pupal) populations of mosquitoes for determining control.

	No Treatment	Pesticide Application	Water management	# Sites for large-scale work
Salt Marsh	<1 per 10 dips	1+ per 10 dips	5+ per dip[a]	1 dip station per 250 acres

Freshwater				
Ground	<1 per 5 dips	1+ per 5 dips	Variable	Not applicable
Aerial	<1 per 10 dips	1+ per 10 dips	Not applicable	1 dip station per 250 acres

[a]Numerous additional factors go into determining water management options for OMWM.

Projects have an obligation to ensure that all alterations function as intended without adverse effects on the environment. Post-alteration work for water management will also monitor vegetative re-growth, changes in fauna and notes on whether or not the hydrology of the site is as intended. When projects have historical data that establishes a pattern of breeding at a given site, they may conduct pre-treatment work.

2. Adult Populations. No adulticiding program will be conducted on a routine, pre-scheduled basis (i.e. once per week, regardless).

a. Monitoring for Adulticiding

Table 3. Adult mosquito monitoring techniques and thresholds for adulticiding.

Monitoring Mechanism	Rate to trigger adulticiding
Light traps	Human-biting mosquito counts exceed five per night
Landing counts	Landing count rates exceed one per minute
Complaint calls	When complaint calls exceed two per geographical area (this area will vary but assume approximately one square mile)

Projects should increase their efforts to understand the impact of adulticiding on mosquitoes. Projects should cross-reference complaint calls with adulticide applications and record the number of calls coming in the week before an application and in the following week (this work may be done during the winter for the previous season). In addition, projects should conduct before and after landing counts and/or light-trap counts for ten percent of their adulticide applications. Landing counts should be taken within 48 hours pre- and post-application at the same location both times. Light trap samples should be from the same trap and for the same time period before and after treatment. Where possible, non-treated areas similar to the treated area should be checked to determine population trends outside the spray zone.

B. Standards for Physical Control. Altering or eliminating mosquito breeding sites range from proper disposal of tires through analyzing drainage systems to creating entire new open marsh water management systems. Physical Control refers specifically to alterations to breeding habitat to prevent mosquitoes from maturing to adulthood. Physical Control is divided further into three types:

Source Elimination: Completely eliminating the breeding site not just the mosquito breeding. Source elimination is generally limited to breeding habitats created by humans in non-wetland areas.

Source Maintenance: Maintaining potential breeding sources in such a way that mosquitoes cannot become a problem.

Source Reduction: Reducing the ability of an area to breed mosquitoes. It differs from source maintenance in that the existing habitat is breeding mosquitoes whereas, if a maintenance program is running as designed, mosquito breeding should not occur. Once a source reduction project is completed, it will, in most cases, require at least some source maintenance in order not to return to being a mosquito-breeding habitat.

The Massachusetts DEP has recently (March 1997) issued a Stormwater Policy Handbook and a Stormwater Technical Handbook. These provide guidelines for stormwater management and should be used to determine appropriate control measures that MCPs should implement. Currently, the primary causes for concern regarding physical control is that there aren't always adequate records of the reasons for a specific maintenance project nor are there also adequate site plans by which it can be determined that increases in ditch cross-section and/or length are not occurring.

C. Standards for Chemical Control.

Projects must comply with regulations for aerial applications of pesticides.

For truck-mounted adulticiding, projects should notify the public through the print media, between March 1st and May 1st of each year, as to the areas that may be treated, the pesticide to be used and a number to contact for more information or to request exclusion from treatment.

As education is a primary aspect of an IPM program, projects are encouraged to develop educational flyers covering such aspects of their work as pesticide use, water management, and property-owner mosquito control. Flyers may either be developed in-house or be obtained from the state or other agencies. Aside from the pesticide applicator recertification requirements, programs are urged to provide opportunities for staff to increase their knowledge about mosquitoes, wetland, and mosquito control.

D. Standard Operating Procedures during EEE problem.

When surveillance data points to increasing levels of EEE risk, DPH notifies the SRMCB and regional MCP superintendents. The EEE Surveillance Program informs MCP superintendents of isolations of EEE in their districts and the districts, in turn, provide feedback to DPH regarding population and life stage indices for critical mosquito species. At certain defined interim levels of risk as outlined in the "Vector Control Plan," MCPs may be asked to increase their ground control larvicide and/or adulticide applications in response to increased EEE virus activity. The SRMCB is responsible for contracting with appropriate mosquito control applicators in the event that aerial EEE vector control is recommended by DPH.

VI. Recommendations

A. Legal, Organizational and Fiscal Aspects of Massachusetts Mosquito Control

The organizational structure and funding for Massachusetts mosquito control programs, be they regional or town based, rests predominately at the level of town government, although the state legislative bodies have a direct influences over eight of the nine MCPs' annual budgets (only East Middlesex is not so affected). In contrast, the overseer of mosquito-control activity in Massachusetts is the State Reclamation and Mosquito Control Board. This is a loose arrangement for delivering a public service that is best applied at a regional level. Lack of control effort in one town can greatly effect the efficiency of control efforts in neighboring towns.

Enabling legislation has been written in a patchwork manner so that there is currently little consistency from project to project. For example, towns in Barnstable County (and formerly in Berkshire) are all members of their respective regional MC project and no individual community may withdraw from the program without changing the legislation as did Chap. 119 of the Acts of 1982 in the case of Berkshire County. This provides an assurance of fiscal and organizational stability that is lacking in other programs. For example, the Essex County and Central Massachusetts projects both went through considerable upheavals in membership between 1988 and 1993. Fortunately, the other projects have remained remarkably stable over the past decade. Maintaining and improving stability, both in membership and funding, is a desirable goal.

This uncertain fiscal picture is further compounded by the fact that all MC projects in Massachusetts are seriously under-funded. In other states, with progressive MC programs, the per capita expenditure varies from $2 upward. In Massachusetts, it averages about $0.50 (based on $2 per household of 4 people). In addition, many other states provide supplemental state funds to encourage non-chemical control efforts and for supportive research and educational activities. No such state support exists in Massachusetts. When supplemental state support has come, it has been for chemical adulticiding in the wake of EEE threats.

To a large extent, funding dictates the control approaches that can be pursued. IPM, source reduction, 1arval control, and adult control represent the four major options in their order of decreasing cost and efficiency.

Thus, poorly funded programs are forced into more reliance on less efficient and more controversial techniques. Larger, better-funded, and stable regional projects can invest in better paid and trained employees, better surveillance and public education programs, and expensive equipment such as helicopters which can broaden the options for safer and more efficient larval control (e.g., granular larviciding with Bti and methoprene).

Given the fact that several different state agencies are concerned with mosquito control activities, the current system of interagency responsibility for overseeing MC activities (i.e., State Reclamation and Mosquito Control Board representing 3 different state agencies) is perhaps the best compromise arrangement. On the other hand, the level of general support services that projects and towns receive from this Board seems to be inadequate.

Recommendations

That new and comprehensive enabling legislation be drafted, reviewed, appropriately revised, and passed into law, which will bring all MC control activity in Massachusetts under the same organizational, fiscal and operational guidelines. This legislation should provide for the following:

1. The State Reclamation and Mosquito Control should have the following personnel:
    a. An Executive Director @ approximately $45,000 per year
    b. An Engineer @ approximately $35,000 per year
    c. An Entomologist @ approximately $35,000 per year

    Not only would this staffing permit the state to conduct research into mosquito control, it would provide a team for rapid response to EEE threats in communities that are not members of established MCPs. This staff would also provide services such as incorporating DEP stormwater management guidelines into Massachusetts MCP Upland Water management operational procedures.
2. An operations budget, above and beyond the normal needs of the SRCMB, for research and development. A minimum of $50,000 per year is suggested.
3. A competitive grant fund (funded by the state, administered by the Executive Director of SRMCB and advised by an ad hoc panel of outside experts) to support IPM related research and delivery programs within the state mosquito control enterprise. This should provide support for studies such as: cost/benefit analysis of mosquito-control programs; development of human annoyance thresholds (HAT); improved methods for monitoring and predicting mosquito population levels;

development, evaluation, and implementation o£ new, non-chemical mosquito management techniques (e.g., open marsh management and biological control); management of pesticide resistance, drift and other use exposures; impact of MC activities on surface and ground water, and on non-target organisms; and the biology and role of selected species in disease transmission.

4. The SRMCB should establish a committee to work with their staff to develop best management practices (BMPs) for all aspects of mosquito control, the results of their work being used to update the GEIR on a regular basis. The committee should include four mosquito-control superintendents, four representatives of environmental agencies (federal, state or private) and one at-large member to serve as chairperson. Their first order of business should be to develop a set of BMPs for freshwater drainage maintenance for mosquito control. These BMPs should establish strict definitions for projects in which the mosquito control exemption from the Wetlands Protection Act may be applied.

5. MCPs must have the authority to deny requests for maintenance work that does not have a mosquito-control component. Because these requests are often made by the same persons or municipalities which provide funding to the MCPs, the SRMCB must be willing to act as an appeals board, to which a request for work may be sent by an applicant in the event the mosquito control program denies the request.

6. Limit mosquito control activity to regionally based regional mosquito control programs which can be organized by the appropriate public vote. The SRMCB should organize the regional based mosquito control programs and appoint project or district commissioners. The SRMCB should select Commissioners from candidates proposed by authorized Boards/individuals from the cities and towns of the mosquito control projects or districts.

7. A flexible and appropriate system of tax assessment which allows for budgets that are adequate to provide for the implementation of the most contemporary and least risky strategies for controlling mosquitoes.

8. A legal system whereby all major zoning and construction plans in the Commonwealth are reviewed by the executive director of SRMCB and the appropriate county MC director for their potential impact on mosquito populations and human health.

B. Operational Aspects of Massachusetts Mosquito Control

Operational programs in Massachusetts could legally be using chemicals (approved by EPA and the Massachusetts Pesticide Board) that are significantly more hazardous than those used in current practice. This suggests that knowledge and sensitivity for the environment and human safety are generally being considered by the existing control programs. As already indicated, funding levels seldom allow projects to follow the optimum operational course. Despite these fiscal constraints, projects have significantly changed their operational methods in recent years toward more source reduction work such as the Open Marsh Water Management projects in Essex, Norfolk and Plymouth Counties. Most projects also use more selective and environmentally compatible larvicides such as Bti and methoprene.

The operational recommendations that follow are predicated on additional and adequate funding being available for implementation.

Recommendations

1. All MC Projects should build their programs around the IPM strategy of keeping human annoyance below threshold levels as given in the Standards of this GEIR.
2. Control methodology should be source reduction whenever possible and larvicidal control when it is not. Projects should work closely with the DEP water quality certification program and the Natural Heritage Endangered Species Program to minimize negative impacts of source reduction to wetland habitat and/or rare or endangered species. The most target-selective and environmentally compatible larvicides (e.g., Bti, methoprene) should be used whenever possible regardless of cost considerations.
3. Saltmarsh mosquito control efforts should emphasize OMWM. All OMWM proposals should include plans for filling many of the old grid ditches in Massachusetts salt marshes which do not function in a productive way and which must regularly be cleaned in order to prevent breeding in the ditches themselves. This will gradually eliminate the controversy over the continuing need to clean these ditches and the problem of what to do with the resulting spoil that is created.
4. Document location, length, and cross-section(s) of all drainage systems maintained by the project and have that information available in an easily understood format for public inspection.

Exemption from the permitting process extents only to those drainage systems for which adequate historical records of maintenance work exist.

5. The SRMCB should create a list of pesticides approved for mosquito control in Massachusetts. Adulticides should be from Categories III and IV and larvicides should be from Category IV.

6. Adulticiding should only be carried out in emergency situations involving disease threats or pest densities which consistently exceed the human annoyance threshold.

7. For large-scale adulticiding, only ULV-cold fogging should be used. For spot treatment around recreation areas or other areas where public events are to be held, portable mistblowers using permethrin as a residual pesticide can be used.

8. Aerial applications should be restricted to granular formulations in areas where drift could be a significant problem. Sometimes some drift is desirable so as to reduce the chance of gaps between application swathes. In such cases a liquid formulation may be a better choice. At this time liquid formulations are also significantly cheaper, making larger applications, and more effective control, easier. Increased use of helicopters for aerial larviciding in coordination with the use of drift-suppression agents and technologies should be encouraged (particularly for enhanced larval control in inaccessible habitats such as salt marshes, wooded swamps, vernal pools, etc.).

9. Projects should file a post-treatment report for aerial applications with the Pesticide Bureau which gives location and acreage actually treated. The pre-application forms do not always accurately represent what actually happened.

10. Chemical-use reporting needs to be monitored to ensure uniformity and accuracy in reporting. Previous reports contained such problems as no units are given on the 1993 through 1995 Cape Cod report for Bactimos (BTI), two different EPA registration numbers for Bactimos are given in the 1993 Cape Cod and Central Massachusetts MCPs reports, and briquets are variously reported in terms of number of briquets, pounds of briquets or pounds of active ingredient. The Pesticide Bureau should insist that yearly chemical-use reports be filled out according to standardized procedures. Reports should be checked as they come in to ensure that standardized reporting procedures are followed.

11. All pesticide storage areas should be equipped with smoke, fire and security systems. A standard procedure should be developed for the disposal of all insecticidal materials used in Massachusetts for mosquito control. The State Pesticide Board should encourage manufacturers of such products to market reusable containers. A standard procedure should be developed for the clean-up of accidental spills of insecticides. Proper use of absorbent materials and the disposal of such materials are necessary. Proper attire during formulation and application of insecticides should be made mandatory for all individuals involved in these processes.

C. Research Needs

There is a need in the mosquito control process in Massachusetts for a strong, operationally focused, research effort in freshwater wetlands, exclusive of chemical application techniques. This is not to condemn current research efforts, for we know more about EEE mosquitoes than ever before, have improved saltmarsh mosquito control dramatically, and have made improvements in both chemicals used and methods of chemical use over the past decade. But there is a need for research to assess the environmental impacts and efficacy of the current MCP programs relative to the freshwater environment.

Additional research on topics such as long-term effects of OMWM, economically viable control of *Cq. perturbans*, and mosquito control in endangered species habitats also require attention.

<u>Recommendations</u>

1. For water management practices, monitor impacts on animals on a case-by-case basis, depending on the site and establish vegetation transects to document changes in wetland vegetation.
2. Develop a unified data base that documents mosquito populations on an ongoing basis from regular monitoring sites. Establish state standards for monitoring mosquitoes and provide training to mosquito control project staff in data collection and management.
3. Conduct comparative studies with different management approaches (e.g. pesticide applications vs. water management).
4. Develop a Geographic Information System (GIS) with known breeding sites and areas of historical water management activities.
5. Qualify sites on the basis of need for control, based on breeding (potential or actual), mosquito

species, proximity to human activity, level and type of human activity, and type of wetland habitat affected.

6. Create an ongoing research partnership with NHESP to document wetland types, etc.. Mosquito Control Projects have knowledge and expertise about wetlands that could be invaluable to NHESP.

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