MASSACHUSETTS MOSQUITO CONTROL

OPEN MARSH WATER MANAGEMENT STANDARDS

MAY 2010

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May 2010

Compiled and edited by the Massachusetts Open Marsh Water Management Workgroup

Massachusetts Mosquito Control Districts

Bristol County Mosquito Control Project

Cape Cod Mosquito Control Project

Plymouth County Mosquito Control Project

Norfolk County Mosquito Control Project

Northeast MA Mosquito Control and Wetlands Management District

Massachusetts Department of Agricultural Resources

State Reclamation and Mosquito Control Board

Massachusetts Fish and Wildlife Service

Natural Heritage and Endangered Species Program

Massachusetts Office of Coastal Zone Management

Massachusetts Department of Environmental Protection

Massachusetts Audubon

The design of this Standard draws extensively from the original Essex County Mosquito Control Project's Standards for Open Marsh Water Management developed by Montgomery et al (1983), and the Northeast Massachusetts Mosquito Control and Wetlands Management District's OMWM Standards, Sullivan et al (2008). We wish to thank these authors for their permission to use materials from these manuals.

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1. INTRODUCTION

The purpose of the Open Marsh Water Management (OMWM) Standards is to function as the operational guidelines for mosquito control professionals for determining where and when it is appropriate to implement OMWM on salt marshes in Massachusetts. The Standards will assist mosquito control professionals in determining the effectiveness of the OMWM mosquito abatement modification. The Standards should help to define and standardize criteria, techniques, terminology, procedure and record keeping for Mosquito Control District (MCD) activities not regulated by the US Army Corps of Engineers.

2. SITE SELECTION

Sites will be identified from one or more of the following sources: MCD records, (adulticiding, larviciding, inspection or investigation) municipal, State or Federal official and/or affected private landowner.

3. SITE CRITERIA

Mosquito Control Districts consider a pre-monitored site appropriate for proposed OMWM modifications if the following apply:

> Sampling of the site documents the development of 2 mosquito broods / season. A mosquito brood is defined as "*All the individuals that hatch at about one time, from eggs laid by one series of parents and which normally mature at about the same time*." (from the Torre-Bueno Glossary of Entomology 1937, revised 1989).
>
> Mosquito broods can be caused by tidal event, fresh water influence or precipitation typically of an inch or more but dependent on previous marsh saturation.
>
> Species composition consists of nuisance mosquito population or a mosquito population of public health concern[1].

The MCD may re-monitor a site at any time.

4. SITE PARAMETERS

Mosquito Control District personnel use their experience and field expertise (best professional judgment) to define a site's limit (bounds) at time of site set-up. To determine the limit of the site, the MCD will first define the approximate extent of anticipated OMWM modification (direct impact). The area of likely indirect impact resulting from OMWM modifications is then estimated. Other considerations to weigh for determination of a site's limits include the following: potential mosquito habitat, existing topography, physical features (grid ditches,

[1] See Appendices: "Current Mosquito Species of Concern for Coastal Massachusetts". This list is not meant to preclude any mosquito species that fit either of the above categories but not currently listed.

creeks etc.), property ownership, crossings, restrictions, major water features and adjacent OMWM site limits.

5. SITE SET-UP

Locating Transects

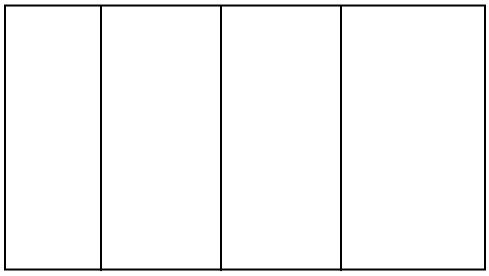
Once the limit of a site has been estimated, the MCD will establish appropriate monitoring locations to measure changes to the marsh that may occur as a result of OMWM modifications. Random sampling along transects will be performed to document hydrology and vegetation data. Mosquito sampling will occur at randomly selected and fully recoverable dip stations (RDS). See Section 8. below.

Transects will be oriented perpendicular to the topographic gradient (e.g. generally from creek/ditch edge to upland edge) according to a consistent compass bearing (Figure One). If there is no clear topographic gradient and/or there is no main creek, ditch or channel, then transects will be set by the MCD's best professional judgment by creating an arbitrary line parallel to the edge from which randomly generated transect lines will run through the area of proposed OMWM modifications.

Ordinarily three transects will be sufficient for each site. However, for narrower or linear sites, more than three and shorter transects may be used (see below). Transect locations along the baseline will be determined using a calculator (with a function for generating random numbers) or another random number generation method. The random number selected represents the distance in feet from the beginning of each section and marks the starting location for each transect. To improve distribution of transects, the randomly generated number can be used to represent the percentage of the site width and transects located accordingly. If the randomly generated location of a transect places it in a ditch or within three meters of another transect, another random number will be generated to determine that transect location.

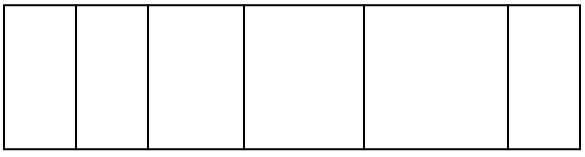
Figure 1: Transect Orientation

Upland Edge



Main Channel/Creek Edge

Upland Edge



Main Channel/Creek Edge

6. DATA COLLECTION EFFORT

While monitoring, technicians should to the extent practicable, record occurrences of interest such as wildlife (i.e., birds, mammals, plants, insects, etc.). All technicians are instructed in basic field identification and are equipped with field guides, binoculars and hand lenses to assist them with the task. MCDs will collect data from each site relevant to general observation, fish, mosquito, hydrology, soils and vegetation.

Raw Data Records

Raw data collection sheets, both pre and post modification, will incorporate general site information pertinent to the data collection visit. Each site is identified according to individual MCD format i.e., "# - municipality". The site identification is recorded along with the date of data collection, the time and duration on site, the technician's name (mosquito control professional tasked with collecting and recording data), the most recent high and low tide events (those of greatest potential influence to the site for that monitoring period), basic weather conditions (such as sunny, cloudy, wind speed and direction, precipitation totals etc.) and any human activity noted on or in the immediate vicinity of the site during the specified monitoring period. Air temperature is measured with a "red liquid" thermometer (or similar) for approximately 5 minutes.

Timing for Pre Modification Surveys

The MCDs conduct pre modification field surveys of all monitoring parameters to collect baseline data and assess a site for potential OMWM modification. Much of the information collected from the site is recorded on OMWM Pre Data Sheets and Summary Records (see appendices). A site should be visited monthly following a flooding event to capture data over a 5 month period (typically between May and September).

Timing for Post Modification Surveys

The MCDs conduct post modification field surveys of all monitoring parameters to measure efficacy of the modifications on mosquito populations and potential impacts to vegetation and hydrology. Much of the information collected from a site is recorded on OMWM Post Data Sheets and Summary Records. (See appendices). A site is monitored for all parameters at one year, two years and five years post site implementation. Post modification data collection is conducted monthly over a 5 month period (typically between May and September). Post modification mosquito population sampling should occur simultaneously with known larval presence on the marsh as evidenced by other field surveys, larviciding records etc. If the technician notes any conditions on site related to increased mosquito activity, poor vegetation recovery, erosion, sedimentation or break down of infrastructure it will be noted and remedied as soon as feasible and/or as necessary.

Fish Sampling

Technicians will record relative abundance of fish at each recoverable mosquito dip station, RDS. The technician notes and records the presence of live fish within a 3 meter radius of each recoverable dip station. Presence of fish is inferred when fish are seen in the water, vegetation or muck or if a fish-like disturbance/movement is noted in the water, vegetation or muck. Data sheet entry for fish occurring at RDS is as follows: dry (no water) = -1, no fish = 0, 1-3 fish = 1, 4-10 fish = 2 and 10+ fish = 3.

Mosquito Sampling

Immature Mosquito Sampling Stations

The marking of potential larval habitats is based upon the MCD professional's experience and field expertise or best professional judgment. The goal when marking potential larval sites on a marsh is to document mosquito production efficacy of OMWM modifications. Potential larval habitats should be re-identified post OMWM modification. Sampling points are generally considered to be the whole panne or the area of potential mosquito developmental habitat associated with a distinct marsh feature such as a panne. The exception to this rule occurs when dealing with very large or very small areas.

In cases where mosquito production is occurring in a small pocket (< 3ft ^{2} surface area) the area should be evaluated in relation to other adjacent small pockets. For example, if there are numerous small pockets within 500ft^2 of marsh area, one sampling point can be used to represent all the depressions.

In cases where mosquito production is occurring in large contiguous areas, the area can be marked approximately every 5,000 ft^2. However, the MCD professional needs to consider that in some circumstances sheet water will dry back and concentrate into depressions. These depressions should be marked individually as potential mosquito habitat. The goal is to mark all areas that are likely to produce mosquito larvae, consistently.

It is suggested that in the spring prior to mosquito developmental habitat marking, the site should be inspected within a few days after an event that would create sheet water. This helps reveal areas that may hold sheet water and depressions that have the potential to produce mosquitoes. An examination of the plant communities and hydrological characteristics will help identify the depressions.

Once all potential larval habitats are identified, fifteen (15) stations will be randomly selected, flagged and labeled for full recoverability.[2] The location and corresponding flag number should be noted on the Site Map and entered with GPS description data (to within 5 meters of accuracy) on a recoverable dip station record. The observer may choose to randomly relocate any given station within the first month of monitoring if it becomes apparent that it will not support emergence of larvae through the adult phase. Miscellaneous mosquito sampling beyond this is frequently conducted for greater success of OMWM site implementation.

Immature Mosquito Sampling

A standard issue white "dipper" (350 ml) is used to dip for immature mosquitoes. The volume of any given dip will not exceed 350ml / dip but is often less. A dip is typically one smooth motion into the water / submerged vegetation and out keeping the dipper level upon exiting so that the sample does not spill. The technician deliberately targets areas of visible mosquito activity at each RDS but within a three meter radius of the station flag. If there is no available water to sample at the RDS it is considered dry. The technician specifically notes dip samples that contain mosquito pupae. The technician may indicate developmental stages of the larvae

[2] After two seasons, the number of dip stations required will be revisited based upon results of a power analysis to determine the optimum number of stations.

(instar – 1st, 2nd, 3rd, or 4th) or indicate "pupae". The technician may indicate condition of the sample i.e., live, moribund or dead as applicable.

Counting Methods

The technician counts live mosquito larvae and pupae and records the number per dip on the data sheet. Counts are most accurately achieved by "pouring off" larvae and / or pupae one at a time thereby avoiding the potential for counting a part of the sample more than once. Though dip numbers in excess of 200 larvae per dip or greater can be common on the salt marsh, it is difficult to precisely measure these numbers in the field. For this reason, numbers above 30 should be estimated based on technician best professional judgment and recorded within ranges of 31-100, 101-200, and 201 to 500. The midpoints of these ranges (65.5, 250.5, and 350.5 respectively) can then be used for data calculations.

Sampling Timing

Additionally, timing of the pre and post mosquito sampling effort can be determined by: marsh indicators (larval or flooding activity), local tide charts[3] (to predict flooding events) and / or precipitation of 1" or more. Experience demonstrates that it is best to wait 1-2 days after initial flooding of the marsh before collecting mosquito data. This provides more opportunity for complete tidal inundation of a site and greater saturation of the substrate thereby increasing the likelihood of mosquito egg hatching. This delay allows for advanced development of larvae and decreased chance that the technician will miscount due to poor visibility of 1st instar stages. Delayed sampling also allows for predation of larvae by larviferous fish; an important factor in the overall OMWM plan.

Adult Sampling

Adult mosquitoes may be sampled from a recoverable location such as a dip station using the standard "landing rate count". The technician records the number of mosquitoes that are seen landing on their body within a specified time frame, i.e. 1 minute, 5 minutes, etc. Handheld aspirators are an effective means of collecting adults in the field. Identification can be performed in the field by trained technicians. An emergence trap developed to confirm emergence and identification of adult mosquitoes may also be utilized to verify larval field identification.

Species Identification

Samples for identification should be collected that represent each brood whenever possible. Field identification of larvae in later stages (3rd or 4th instar) is acceptable by trained technicians. Mosquito larvae and pupae can be brought to the MCD's facility for rearing and / or detailed examination beneath a microscope. Vials are labeled with the name of the technician, date and location of collection, (site number and sample dip location). Once identified, the species is recorded on the appropriate data sheet / summary and discarded if not being pooled for virus or disease testing. When more than one species is identified the dominant species (species of greater abundance) is recorded as such and other species noted as well.

[3] Though local tide charts can be used to set a general time table for post monitoring, salt marsh habitats can be flooded sufficiently to produce a brood of mosquitoes without indicated tidal activity and on very little rainfall.

Hydrology Sampling

Flooding Events

Tidal influence is measured with a rudimentary black stake tide gauge (1" x 1" x 48" - or other) and white chalk method.[4] The stake is placed at an RDS and a measurement of the elevation from the marsh surface to a mark on the stake is used as a predetermined standard. Each time the site is monitored the technician measures the elevation between the remaining chalk (line) and the reference mark and then re-chalks the stake to either water level or marsh surface as applicable for the next reading. "Marsh to mark" and "re-chalk" measurements are recorded. The difference between the previously re-chalked measurement and the current marsh to mark measurement is calculated to indicate previous flooding over the marsh surface.

Pore Water

Pore water wells will be located on the above described transect lines with one at the end of each transect (highest and lowest topographic points) and one located about halfway along each transect. Seventy (70) cm "pvc" pipe will be perforated along 60 cm of the length. The bottom of the pipe will be capped, and the pipe will be driven to a depth of 60 cm, with 10 cm extending above the marsh surface. The wells will be capped loosely to prevent rainwater from entering the well. The cap will have a small hole in the center for venting. Pore water measurements will be taken by recording the distance from the top of the well to the water surface within the well, minus the height of the well above the marsh surface. The height above the marsh surface should preferably be measured each time but at least once prior to monitoring season to adjust for movement of the well due to ice flow, freezing/thawing, etc. If the well is dry, that will be recorded on the data sheet. Pore water will be checked monthly throughout the monitoring period, within 5 days after a monthly spring tide. Sampling timing should occur 3 hours before or after a low tide. Pore water salinity is measured utilizing a standard refractometer that is calibrated with distilled water prior to each reading.

Precipitation

A wedge shaped rain gauge is typically fastened to a stake. Rainfall is measured in inches or millimeters but standardized throughout any given monitoring interval. Whenever possible the technician collects rainfall data shortly after a rain event. A rain gauge which is located on an adjacent site may be used as a measure provided it is relatively close in proximity – within 500 meters. Rainfall collection dates and amounts are noted on the data sheet, tallied between site visits and totaled on the summary sheets. Though not ideal, alternate methods may be used for documenting weekly precipitation amounts such as a trusted web site or other reliable resource.

Salinity

Surface water salinity will be measured at each mosquito sampling station utilizing a standard refractometer calibrated with distilled water prior to each reading. The technician carries an eye-dropper for collecting a water sample from approximately 1" – 3" below the surface of the water. Three samples are taken and discarded to clear the eye-dropper and the 4th sample is

[4] Though this method is not precise, more accurate and costly methods of measurement are unnecessary to the mosquito control professional for designing effiective modifications for an OMWM site.

measured. The technician cleans the instrument with distilled water and dries the instrument with a "Kim wipe" if available.

Soils Sampling
Rudimentary soil core profiles by hand auger may be taken to determine the feasibility and or extent (mainly depth dimension) of a proposed alteration relative to subsurface soil condition. Locations where sampling may occur: reservoirs, ponds, and selective ditches.

Vegetation Sampling
Technicians collect vegetation data using a point-intercept method along transects. Vegetation sampling is conducted once annually in late summer to early fall (July to October). The interval for point data collection along each transect will be every meter if the transect is 30 meters long or less, or every 2 meters if the transect is longer than 30 meters. At each interval, all species of plants intercepting the line are recorded. Observers only work transects from one side to avoid vegetation trampling.

Data Analysis
Vegetation data are recorded on a Vegetation Record. Data will be analyzed to determine percent frequency (indicative of the overall vegetative cover) and absolute frequency (the number of one-meter intervals at which a plant species is present). To determine percent frequency for each transect, the absolute frequency is divided by the total number of intervals in each transect. These observations are designed to examine changes in vegetation after OMWM modification.

7. SITE DOCUMENTATION

Permanent Site Records
The Mosquito Control District will keep a permanent record of each OMWM site. Maps, field maps measurements, site imagery, preliminary and post monitoring data, sample locations (recoverable dip stations, groundwater sampling stations, vegetation transects, and recoverable photo stations will be archived. Each implemented site (post) should also have notification records i.e., agency, advisory committee, and property owner. All relevant correspondence (conversation, meeting and written record) and any field notes or calculations pertinent to the site should be archived as well. All pre and/or post raw data (mosquito, hydrologic, soils, and vegetation) will be made available upon request.

Site Mapping
Massachusetts GIS mapping data and occasionally aerial photography are used throughout project development. Available GPS information (within 5 meter accuracy) will be incorporated within layers as deemed pertinent to site design development. Layers that might be included are not limited to the following: ortho-photography, topography, property ownership, wetland types and boundaries, ACEC Designation, Outstanding Resource Waters,

and Natural Heritage Designations - Priority Habitats of Rare Species, Estimated Habitats of Rare Wildlife and Certified Vernal Pools[5].

The site map identifies: site limits (perimeter), transect locations, groundwater well locations, and recoverable dip stations, and recoverable photo stations within 5 meter accuracy. These features are overlaid as layers or digitally drawn using GIS tools.

Site Design
MCD professionals create a specific design for each site based on data collected, preexisting conditions, site influences and general observations. Available GIS data (orthophotography or similar) are used as a base map. Proposed modifications are numbered and labeled accordingly. A "Legend" is included that specifies a color code for digitally drawn modifications. The site design includes: estimated high tide line and proposed alterations i.e., staging area, access and egress routes, site preparation requirements, erosion and sediment control device locations, temporary designated stockpile areas, and on site spoil disposal areas if applicable.

Site Summaries
At the end of each monitoring period, the site is evaluated utilizing Site Summary Codes (see appendices). Information recorded should include an approximate assessment of site characteristics relative to ownership, adjacent upland types and land use, ground conditions, general hydrology and invasive species composition.

The preliminary data is summarized for Advisory Committee review. Data summarized include but are not limited to dates of sampling, mosquitoes - corresponding mean immature mosquito range per # of dips taken / collection date, mosquito range per station and mosquito species identified, groundwater measurements, vegetation – percent frequency and absolute frequency and for fish - relative abundance range.

Proposed modification features are measured and approximate dimensions for each recorded on a Proposed Feature Dimensions Summary Record. An estimate for volume of spoil displaced (expressed in cubic yards) is calculated for each feature. The total volume (expressed in cubic yards) for all proposed on site features is also recorded.

The post data are summarized for Advisory Committee review. Data summarized include but are not limited to dates of observation, mosquitoes - corresponding mean immature mosquito range per # of dips taken / collection date, mosquito range per station and mosquito species identified, groundwater measurements, vegetation – percent frequency and absolute frequency and for fish - relative abundance range.

Site Photography
A fully recoverable photo station (RPS) is marked by GPS coordinates (+ or – 5 meter accuracy) and a marker (i.e. wood stake) inserted in its place and replaced for the duration of

[5] Additional information on the Massachusetts Endangered Species Act, MESA and OMWM activities within designated habitat can be found in the Appendices.

the monitoring period. This location is selected on its ability to provide optimal coverage of site characteristics. A digital panoramic record or aerial photograph consisting of 1 year preliminary and 1 and 2 year post alteration imagery of the site is recorded at time of peak vegetation – usually August.

Site Notification

A site map and proposed site design will be circulated to all members of the MCD OMWM Advisory Committee for review and comment prior to construction. Advisory Committee members should review, supply comments and make suggestions relative to their particular agency's expertise to the MCD within 30 days of receipt of the information. If the MCD receives no comment within 30 days it will be assumed that there is no comment and implementation of site design will proceed.

Acknowledgements in alphabetical order:

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Priscilla Matton	Bristol County Mosquito Control Project
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David Paulson	Natural Heritage and Endangered Species Program
Richard Pollack	Harvard School of Public Health
Mike Stroman	Massachusetts Department of Environmental Protection
Emily DW Sullivan	Northeast MA Mosquito Control & Wetlands Management District

APPENDIX A
HISTORY OF SALT MARSH MANAGEMENT FOR MOSQUITO CONTROL IN COASTAL MASSACHUSETTS

Ditching

There are some historic references to Native American tribes, who inhabited coastal areas of New England, conducting ditching on the salt marsh. However, extensive ditching of the marsh wasn't practiced until after the arrival of the first settlers. Ditching was largely conducted on salt marshes to improve conditions there for pasture and grazing of livestock but also to promote larger yields and allow easier access to harvest hay. Salt marsh vegetation provided for other uses such as thatch for roofing, salt grasses for insulation, but largely for livestock bedding and feed.

Ditching on a much larger scale was done to provide access by gondolas to outlying salt marshes for harvesting salt hay and to accommodate commerce between settlements. Natural creeks were widened, extended or rerouted to neighboring settlements. Ditching became a profession and apprentices were paid 16 cents per rod. In some cases, tolls were charged to navigate some creeks and channels.

Grid Ditching

The grid ditch system still evident on our salt marshes today, were dug by hand between 1928 and 1934. The primary purpose of this era of ditching was to put as many people to work as possible, as this was the time of the great depression. No entomological studies were conducted in conjunction with this ditching effort; mosquito control was a secondary consideration at best. However mosquito control was achieved by default as practically every square inch of marsh was drained by the extensive project. Some engineering studies were done to determine where and at what intervals ditches were dug. Ditches were dug in straight rows by hand with sod saws and two man shovels. In 1934, at the peak of this ditching effort, over 11,000 men were employed digging ditches and when completed nearly 3,000 linear miles of salt marsh ditch were dug in Massachusetts alone. Virtually all salt marsh in New England was ditched with the exception of one marsh in Rhode Island.

Later in the late 1940s and early 1950s soldiers returned home from World War II. Housing shortages were a big problem in the more populated areas particularly in and around Boston. A generation of young families, eager to get their lives back on track migrated to the north shore of Massachusetts to start new lives. This migration coincided with the degradation of the grid ditch system created in the 1930s. These ditches had not been maintained and now produced far more mosquitoes then they had initially eliminated. By many accounts it was so bad some considered the area to be almost uninhabitable. A few local programs were established to try to reopen the ditches but it was impossible to duplicate the labor force that had originally created the ditches.

In 1958, a grass roots effort, fueled by public demand for relief resulted in legislation establishing the Essex County Mosquito Control Project. For reasons unknown the project was not formally funded until 1965. Equipment was purchased and a major effort was launched to reclaim salt marsh ditches.

Salt Marsh Ditch Maintenance in Northeast Massachusetts

In the late 1970s, Walter Montgomery was an equipment operator for what was then, the Essex County Mosquito Control Project, ECMCP. Montgomery's primary duty was to maintain the extensive salt marsh grid ditch system, excavated for the most part, between 1928 and 1934. Montgomery recalls using an implement known as a scavel plow; this was a large wedge shaped device mounted under a wing plow and could be attached to the front of a tractor or sometimes towed behind. A scavel plow wedge was basically constructed to the original ditch dimension. The wedge would be dropped into the ditch and the tractor either pushed or pulled it along. As the wedge peeled spoil out of the ditch the wing plow would roll the spoil into furrows approximately six feet wide on both sides of the ditch. These furrows of spoil were then either run over to flatten them or plowed off the marsh.

On a productive day Montgomery recalls completing two or more miles of ditch maintenance but even at that rate maintenance of hundreds of linear miles of ditch was an endless endeavor. It was Montgomery's experience that freshly maintained ditches were really only effective for about two years before requiring additional maintenance. Typically ditches would become blocked on the high marsh and previously drained salt pannes would often reestablish. Montgomery observed that the open water areas of these pannes or ponds didn't have mosquito larvae but the grassy sheltered areas around the edges or isolated depressions adjacent to the ponds, supported mosquito larvae. Montgomery's observations further supported his belief that continued maintenance of the grid ditch system was not productive and furthermore there had to be a better way to manage salt marsh mosquito populations.

In the early 1980s Montgomery was promoted to Field Foreman. This provided him with the opportunity to investigate possible alternatives to ditching. Montgomery became aware of work that was being done in the mid Atlantic states, Open Marsh Water Management, OMWM and wondered if it could be duplicated in the northeast. The Essex County Mosquito Control Project began experimenting with basic OMWM techniques but soon realized that more technical expertise was needed.

Open Marsh Water Management

The origins of Open Marsh Water Management, OMWM, can be traced back to New Jersey in the late 1960s and is directly attributed to mosquito control greats such as Dr. J.M. Jobbins, J.K. Shisler and Frederick Ferrigno. From its inception, OMWM was a collaborative of environmental advocates and mosquito control professionals. Delaware began evaluating OMWM in 1980 (William H. Meredith, Department of Fish and Wildlife, Division Of Natural Resources and Environmental Control / NMCA 1980) and

soon the mosquito control technique was instituted as standard practice there. Maryland also began an OMWM Program under the direction of Dr. Cyrus Lesser.

OMWM in Essex County, MA

In March of 1982 the Town of Rowley received a Coastal Zone Management, CZM grant for $19,800 to study mosquito control practices and the effect of ditching on migrating shore birds, mosquitoes and invertebrates on Rowley salt marshes. Sixteen thousand five hundred dollars were contracted to the Manomet Bird Observatory. The remaining $3,300.00 was used to pay for in kind service to various groups. The Essex County Mosquito Control Project approached the Rowley Conservation Commission and asked to be involved in the study, hoping to promote interest in OMWM and gain technical expertise, which was lacking. This was the beginning of a long and beneficial relationship between mosquito control and several environmental agencies and groups. The premise of this relationship was simple and unspoken; agreeing to disagree on subjects of controversy and focusing on OMWM which could be mutually beneficial to the environment and simultaneously provide for mosquito control. The results of the study were presented to both the Rowley Conservation Commission and CZM in a report entitled *The effect of ditching for mosquito control on salt marsh usage by birds in Rowley, Massachusetts* (published as Clarke, 1984).

In 1983 a $10,000.00 grant was secured from the U.S. Fish and Wildlife Service to continue the study. The Essex County Mosquito Control Project enlisted the help of many other mosquito control professionals from New Jersey, Delaware and Maryland as well as Dr. Thomas Hruby of the Resource for the North Shore and Office of the Massachusetts Audubon. Together two pilot projects were designed which used the New Jersey Standards for OMWM as guidance (Dr. Kenneth Bruder, 1980). An experimental permit was secured from the U.S Army Corp of Engineers. Findings of the study were published in the Journal of Field Ornithology, in the spring of 1984.

Fairly quickly Montgomery and others realized that they needed to develop an OMWM Standard which would reflect the regional characteristics of Essex County salt marshes; particularly differences in tidal range in comparison to that of New Jersey. The Standards would function as an operational manual and be designed to help mosquito control professionals and other interested agencies to understand the process of implementing OMWM. These Standards became the original *Essex County Mosquito Control Standards for Open Marsh Water Management* (Montgomery, 1982). It also became evident that the public would need to be educated as to the potential benefits of OMWM as compared to traditional maintenance of the grid ditch system. From the public's perspective, mosquito control professionals had been draining salt marshes for years and now here they were proposing to deliberately hold water on the marsh. A media blitz focusing on newspapers and regional magazines was initiated. Montgomery co-authored a brochure with Dr. Hruby entitled *The Mosquito, the Salt Marsh, and You; Controlling mosquitoes on Essex County salt marshes* (No date).

In 1984, ECMCP applied for and received its first Army Corp of Engineers Permit which included the original Essex County's *Standards for OMWM*. The permit provided ground rules for the development of the OMWM Advisory Committee. The Advisory Committee's role was twofold: to act as a watch dog group to ensure that concerns of all the various agencies and environmental interests were considered as well as to provide technical assistance and expertise falling beyond the scope of mosquito control personnel.

Fresh Water Marsh vs. Salt Water Marsh

Open Marsh Water Management in Essex County has been scrutinized from many angles over the course of the years. The U.S. Fish and Wildlife Service had its own internal debate which posed numerous questions culminating in concern regarding the effects of OMWM on the productivity and value of bordering fresh water marshes. Some experts preferred salt marshes and were not concerned by encroachment into the fresh water interface. Some put more value in maintaining the fresh water marshes. After much discussion a compromise was reached and incorporated into the Standards. Thus began the origins of an alteration technique known as the "perimeter" ditch (sometimes called a gutter ditch), which could be excavated on the estuarine interface between salt and fresh vegetation. A perimeter ditch allowed for fresh water sheet flow to its boundaries, simultaneously providing for its drainage away from the salt marsh surface, thereby stopping further encroachment of fresh water vegetation on the marsh; native salt marsh vegetation flourished. From the mosquito controller's perspective these ditches provided much needed tidal circulation into the upper reaches of the salt marsh (typically more productive mosquito habitat) and encouraged movement of naturally occurring mosquito eating fish throughout a site.

As the debate over fresh marsh versus salt marsh evolved, concerns also rapidly grew regarding *Phragmites australis* and its invasion of the salt marsh. General consensus became that fresh water intrusion on salt marshes had a negative impact to the resource area. The perimeter ditch quickly became an effective means by which to redirect excess fresh water and thereby diminish Phragmites vigorous march across the marsh. This is perhaps the principle reason why OMWM was embraced so enthusiastically by a number of those in the environmental community. Open Marsh Water Management was seen as a means to restore salt marsh. *Sanctuary: Journal of the Massachusetts Audubon Society* (Buchsbaum, 1989). Massachusetts Audubon continued to conduct studies on these and other OMWM projects from 1985 through 1989 and results were presented at the New England Estuarine Research Society Conference in June of 1989.

Chapter 410 of the Acts of 1996

In October of 1996 Montgomery and the Essex County Mosquito Control Project received a Massachusetts Wetlands Restoration Award from The Executive Office of Environmental Affairs "in recognition of outstanding contributions to wetlands restoration in the Commonwealth of Massachusetts" and cited a total of 450 acres of restoration on 30 individual sites. It was not long after that Montgomery officially changed the name of the "Project" to reflect the agency's more permanent stature in the

field but also to suggest the solid commitment of the agency to manage wetlands with a long term perspective. Chapter 410 of the Acts of 1996 made it official: ECMCP became the Northeast Massachusetts Mosquito Control and Wetlands Management District, NEMMCWMD or the District.

US Army Corps Individual Permit and the OMWM Standards

The Army Corps permit was subsequently renewed for 3 years each in 1987, 1989, 1992 and 1995. In 1998, at the suggestion of the U.S. Army Corp of Engineers, NEMMCWMD renewed its OMWM permit for 10 years. The District revised and updated the OMWM Standards each time the permit required renewal in order to reflect the development of new strategies, technological advances in equipment, and lessons learned in the field.

OMWM in Coastal Massachusetts

The Plymouth County Mosquito Control Project (PCMCP) held a permit in the 1980's and conducted about a half dozen or so OMWM projects, but the permit was not renewed. In 2001 PCMCP received a 5 year permit and then renewed for 10 years. They have completed 3 projects under the latest permit which expires in 2015.

The Norfolk County Mosquito Control Project (NCMCP) was mentored by the NEMMCWMD in OMWM and received a 5 year permit in 1999. This permit was renewed for 10 years in 2006 after some administrative delays, and will expire in 2016. NCMCP has completed 12 projects. NCMCP and PCMCP collaborated on a joint standards revision in 2005 that applied to their renewed permits.

Bristol County Mosquito Control Project (BCMCP) received a permit in 2002 which expired in 2006. A renewed permit was granted and it will expire in 2011. BCMCP has proposed OMWM projects, but for various extenuating circumstances has not completed any projects.

In 2008, the NEMMCWMD applied for its permit renewal and received a Federal Consistency Objection. The District filed a federal appeal which was later rescinded. A workgroup comprised of the Bristol, Cape Cod, Norfolk, Northeast MA and Plymouth County Mosquito Control Districts, the State Reclamation and Mosquito Control Board, CZM, MA Fish and Wildlife, and MA Audubon was formed to revise the Standards.

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APPENDIX B
CURRENT MOSQUITO SPECIES OF CONCERN IN COASTAL MASSACHUSETTS

The following mosquito species are of concern because of their potential or demonstrated ability to transmit viruses. The remaining species listed are those which have a significant annoyance potential. **Bolded** species are those with larval development habitat found directly in the salt marsh.

Scientific Name	Common Name
Aedes canadensis	"woodland pool mosquito"
Aedes cantator[1]	"brown salt marsh mosquito"
Aedes japonicus	"Japanese rock pool mosquito"
Aedes sollicitans	"golden salt marsh mosquito"
Aedes taeniorhynchus	"Southern salt marsh mosquito"
Aedes triseriatus	"eastern tree-hole mosquito"
Aedes vexans	"re-flood mosquito"
Anopheles punctipennis	"mottle-winged mosquito"
Anopheles quadrimaculatus	"malaria-carrying mosquito"
Coquillettidia perturbans	"cattail marsh mosquito"
Culex pipiens	"northern house mosquito"
Culex restuans	"white-dotted mosquito"
Culex salinarius	"un-banded salt marsh mosquito"
Culiseta melanura	"cedar swamp mosquito"
Culiseta morsitans	
Uranotaenia sapphirina	"sapphire-lined mosquito"

[1] Reference to *Ochlerotatus* has been reverted back to *Aedes* as defined in original or pre 2000 nomenclature. Many professionals of mosquito abatement have made this same decision as it has caused confusion nation-wide.

APPENDIX C
COMMON SALT AND BRACKISH MARSH PLANT SPECIES IN COASTAL MASSACHUSETTS

Agalinis maritime	Salt marsh False Foxglove
Agropyren pungens	Quackgrass
Aster tenuifolius	Aster
Atriplex patula	Marsh Orach
Carex paleacea	Salt Marsh Sedge
Distichlis spicata	Spike Grass
Glaux maritima	Sea Milkwort
Iva frutescens/annua	Marsh Elder
Juncus gerardii	Black Grass
Juncus effusus	Soft Rush
Juncus maritimus	Sea Rush
Lepidium latifolium	**Perennial Pepperweed***
Limonium nashii	Sea Lavender
Lythrum salicaria	**Purple Loosestrife***
Myrica gale	Sweet Gale
Panicum virgatum	Switchgrass
Phragmites australis	**Common Reed***
Plantago maritima	Seaside Plantain
Pluchea purpurascens	Camphor Weed
Polygonom cuspidatum	**Japanese Knotweed**
Potentilla anserina	Silverweed
Salicornia europaea	Common Glasswort
Scirpus pungens	Common 3-Square – Sedge Family
Scirpus robustus	Salt Marsh Bulrush – Sedge Family
Scirpus validus	Soft Stemmed Bulrush – Sedge Family
Spartina alterniflora	Smooth Cord Grass
Spartina cynosuroides	Big Cordgrass
Spartina patens	Salt Hay Grass
Solidago sempirvirens	Seaside Goldenrod
Suaeda linearis	Sea Blight
Typha angustifolia	Narrow-leaved Cattail

*** Bold text indicates invasive species. Follow protocols that prohibit spread.**

APPENDIX D
OMWM DATA RECORD BINDER

OMWM Pre Modification Data Record

Site name or #: _____ Date: _____ Technician(s): _____

Weather: _____ Wind: _____ Air: _____ °F Begin: _____ End: _____ Rain / period*: _____

High tide time: _____ Height: _____ Low tide time: _____ Height: _____ Last Spring Tide _____ Height: _____ Days since LST _____

Tide Gauge from: _____ Tide Gauge up to: _____ Tide Gauge Rechalked: _____ Rise: _____ LRC Interval: _____

Mosquito**

RDS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**Total # of Dips**	**Total #**
Dips																	
Mean / Station																	
Dom sp.																**Mean of all Dips**	
Other sp.																	
LRC																	

Fish**

RDS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**Mean Value / Site**
Value Code*																

Comments

Humans on site: _____ Vicinity: _____ Coastal Birds on Site: _____ Vicinity: _____ Types: _____

* Rain Dates and Amounts: _____

**Mosquito Counts: Dry = 0 / 0-30 = 0-30 / 31-100 = 65.5 / 101-200 = 250.5 / 201-500 = 350.5

*** Fish Counts: Dry = (-1) / None = (0) / 1-3 = (1) / 4-10 = (2) / 11+ = 3

OMWM Pre Modification Data Summary Record

Site #: _____ Municipality: _____ Ownership: _____
Upland Type: _____ Upland Land Use: _____ Fresh Marsh: _____
Marsh Type: _____ Ground Conditions: _____ Hydrology: _____
Dominant Vegetation: _____ Invasive Vegetation: _____

	Date												
Mosquitoes	# of Dips / Site												
	Total of all Dips												
	Mean Mosquito / Site												
	Dominant Mosquito Species												
	Other Mosquito Species												
	Landing Rate Count												
Fish*	# of Wet Stations												
	Mean Value / Site												
	Total Value / Site												
General	Humans												
	Coastal Birds												
	Other												
	Comments:												

Fish *Dry = -1 / None = 0 / 1-3 = 1 / 4-10 = 2 / 11+ = 3 General ** N = None / O = Occasional (1-3) / C = Common (4-10) / A = Abundant (11+)

OMWM Post Modification Data Record

Site name or #: _____ Date: _____ Technician(s): _____

Weather: _____ Wind: _____ Air: _____ °F Begin: _____ End: _____ Rain / period*: _____

High tide time: _____ Height: _____ Low tide time: _____ Height: _____ Last Spring Tide _____ Height: _____ Days since LST _____

Tide Gauge from: _____ Tide Gauge up to: _____ Tide Gauge Rechalked: _____ Rise: _____ LRC Interval: _____

Mosquito**

RDS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**Total # of Dips**	**Total #**
Dips																	
Mean / Station																	
Dom sp.																**Mean of all Dips**	
Other sp.																	
LRC																	

Fish***

RDS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**Mean Value / Site**
Value Code*																

Comments

Humans on site: _____ Vicinity: _____ Coastal Birds on Site: _____ Vicinity: _____ Types: _____

* Rain Dates and Amounts: _____

**Mosquito Counts: Dry = 0 / 0-30 = 0-30 / 31-100 = 65.5 / 101-200 = 250.5 / 201-500 = 350.5

***Fish Counts: Dry = (-1) / None = (0) / 1-3 = (1) / 4-10 = (2) / 11+ = 3

OMWM Post Modification Data Summary Record

Site #: _____ Municipality: _____ Ownership: _____
Upland Type: _____ Upland Land Use: _____ Fresh Marsh: _____
Marsh Type: _____ Ground Conditions: _____ Hydrology: _____
Dominant Vegetation: _____ Invasive Vegetation: _____

	Date												
Mosquitoes	# of Dips / Site												
	Total of all Dips												
	Mean Mosquito / Site												
	Dominant Mosquito Species												
	Other Mosquito Species												
	Landing Rate Count												
Fish*	# of Wet Stations												
	Mean Value / Site												
	Total Value / Site												
General	Humans												
	Coastal Birds												
	Other												
	Comments:												

Fish *Dry = -1 / None = 0 / 1-3 = 1 / 4-10 = 2 / 11+ = 3

General ** N = None / O = Occasional (1-3) / C = Common (4-10) / A = Abundant (11+)

APPENDIX E
OMWM SITE SUMMARY CODES

Category	Type	Code	
OWNERSHIP			
	Private, unspecified	1	
	Private, agricultural	2	
	Private, conservation	3	
	Public, unspecified	4	
	Public, agricultural	5	
	Public, conservation	6	
	Public, wildlife refuge	7	
UPLAND TYPE			
	Hilly (Solid rock)	1	
	Hilly (Soil or glacial deposits)	2	
	River or coastal valley	3	
	Man-made (Causeway, railroad, buildings…)	4	
UPLAND LAND USE			
	Business / Industrial	1	
	Residential, developed	2	
	Residential, undeveloped	3	
	Agricultural	4	
	Transportation	5	
	Conservation	6	
FRESH MARSH			
	None	1	
	Less than ½ upland edge	2	
	More than ½ upland edge	3	
MARSH TYPE			
	High	1	
	Low	2	
GROUND CONDITION			
	Firm	1	
	Soft	2	
	Very Soft	3	
HYDROLOGY			
	Unditched, “natural”	1	
	Ditched, poorly drained	2	
	Ditched, well drained	3	
	Restricted, culvert / roadway etc.		R
INVASIVES			
	Phragmites australis	1	
	Lepidium latifolium	2	
	Lythrum salicaria	3	
	Other (List species)		

APPENDIX F
OMWM AND THE MASSACHUSETTS ENDANGERED SPECIES ACT (MESA)

The Massachusetts Endangered Species Act (M.G.L. c.131A) and its implementing regulations (MESA, 321 CMR 10.00) establish procedures for the listing and protection of state-listed plants and animals. The MESA regulations include project review filing requirements for projects or activities that are located within a Priority Habitat of State-listed Rare Species ("Priority Habitat"). The MESA is administered by the Natural Heritage and Endangered Species Program (NHESP) of the MA Division of Fisheries & Wildlife, and prohibits the "take" of state-listed species. The "take" of state-listed species is defined as "in reference to animals, means to harass, harm, pursue, hunt, shoot, hound, kill, trap, capture, collect, process, disrupt the nesting, breeding, feeding or migratory activity or attempt to engage in any such conduct, or to assist such conduct, and in reference to plants, means to collect, pick, kill, transplant, cut or process or attempt to engage or to assist in any such conduct. Disruption of nesting, breeding, feeding or migratory activity may result from, but is not limited to, the modification, degradation or destruction of Habitat" (321 CMR 10.02).

Mosquito Control Districts should consult the most recent edition of the *MA Rare & Endangered Species Habitat Atlas* http://www.mass.gov/dfwele/dfw/nhesp/nhesp.htm to determine if a proposed project will occur within *Priority Habitat* and the relevant NHESP guidance information to determine if direct filing pursuant to the MESA is required.

If a filing with the NHESP is required, filing should consider access, egress, spoil/soil deposition or spreads or other activities related to the project occurring within *Priority Habitat*. In general, the Site Plan should include sufficient detail and mapping to clarify the location of all work areas and the form of work (e.g., mechanical work or hand work).

Within 30 days of receiving a filing, the NHESP will provide a response letter indicating whether or not the submission is complete. If the submission is complete, the NHESP will provide a letter determining if the project will result in a "take" within 60 days of the date of posting of the first letter (321 CMR 10.18). In this letter, the NHESP will determine whether or not a project, as currently proposed, will (a)avoid a "take" as proposed, or with conditions and may proceed without further review, or (b) will result in a "take" of State-listed Rare Species and cannot proceed as proposed (321 CMR 10.23).

If an OMWM project is determined to result in a "take" then it may be possible to redesign the project to avoid a "take". If such revisions are not possible, then OMWM projects resulting in a "take" may only be permitted if they qualify for a MESA Conservation & Management Permit (321 CMR 10.23).

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