INSECTICIDES RECOMMENDED FOR MOSQUITO CONTROL IN NEW JERSEY IN 2012

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INTRODUCTION

The recommendations for 2012 include the use of spinosad (Natular®) as a larvicide, the use of etofenprox (Zenivex®), the observational use of synergized prallethrin/d-phenothrin (Duet®) for adulticiding and the continued use of insecticides being phased out including resmethrin (in Scourge®) and temephos (Abate®).

The New Jersey Agricultural Experiment Station annually reviews the insecticides available for use by the state and county mosquito control commissions and agencies responsible for reducing the populations of nuisance and vector species of mosquitoes in New Jersey. This is done by faculty in the Department of Entomology having experience in mosquito research and control, including factors of safety, economy and efficiency under New Jersey conditions. These recommendations are produced as a service to the residents of New Jersey and are for use in New Jersey only. The New Jersey Agricultural Experiment Station takes no responsibility for their use elsewhere. Selection of insecticides depends on environmental considerations and on continued information exchange between the State and Federal authorities and the professional organizations in mosquito research and control in New Jersey. Professional mosquito control in New Jersey relies on the surveillance of mosquito sources and problems and the proper consideration of options for control, such as water management, biological control, and insecticides. This integrated and comprehensive approach to the control of mosquitoes utilizes all available control strategies to reduce the occurrence of mosquitoes as pests to tolerable levels while maintaining a quality environment.

When mosquito problems necessitate the use of insecticides, it is generally best to employ larvicides and pupicides, as they are directed at the most concentrated developmental stages of the mosquito population and reduce the need for large-scale and expensive adulticiding. Only the public county and state commissions or agencies charged with the responsibility for mosquito control may perform mosquitocidal applications on any scale, large or small. If weather or environmental concerns prevent larviciding, adulticides can be used shortly after emergence before adult mosquitoes have dispersed. The purpose of mosquito control is to reduce nuisance and disease potential, not to eradicate mosquitoes. Adulticiding may be necessary for dispersed or migrating adult mosquitoes but should be avoided. Special attention should be given to the level of mosquito activity and the prevailing environmental conditions in order to insure maximum efficiency of the application.

All applications of insecticides for larviciding, pupiciding, or adulticiding purposes must be consistent with and comply with the principles of integrated pest management (IPM) as described in the APPENDIX (starting on page 12), entitled “Best Management Practices for Mosquito Control in New Jersey”. This text (revised in 2008) is an excerpt of all clauses pertaining to mosquito control in New Jersey from “The Environmental Protection Agency’s Pesticide Environmental Stewardship Program“ and contains detailed and comprehensive (~~http://www-rci.rutgers.edu/~insects/~~psd.htm), information on integrated practices for mosquito control in New Jersey.

For the benefit of mosquito control in New Jersey, information gathered on control efficacy for the target species and any effects observed on non-target species in trial applications of insecticides not included in these recommendations should be shared with members of the Associated Executives of Mosquito Control Work in New Jersey and the NJAES (write to or e-mail Dr L. B. Brattsten, Rutgers University, Department of Entomology, Blake Hall, 93 Lipman Drive, New Brunswick, NJ 08901; brattsten@aesop.rutgers.edu). Please include in your letter details of locations and target species. All such applications of insecticides should follow the manufacturer’s recommendations.

Just as bacteria evolve resistance to antibiotics, mosquitoes evolve resistance to insecticides used for their control. Selection for resistance can result from the repeated use of the same insecticide exclusively and from slow-release formulations of insecticides. To avoid or delay resistance, a variety of different insecticides and other control methods must be used in rotation. Reliance on a single insecticide frequently or over large contiguous areas is likely to produce resistance to that control agent and can also cause cross-resistance to other insecticides. The major larvicides recommended for use in New Jersey, temephos, S-methoprene, spinosad, and BTI are ideal for use in rotations as each has low environmental stability, a separate molecular mode of action, and significant differences in detoxification mechanisms. For adulticiding, malathion is the least likely to trigger evolution of resistance and synergized pyrethroids the most likely.

The table below shows the major modes of detoxification of the three adulticides and the four available larvicides in most mosquitoes. The enzymes catalyzing the oxidations are the large family of cytochrome P450 multipurpose monooxygenases; the enzymes catalyzing the hydrolyses are the equally large family of esterases. BTI is detoxified by a special case of hydrolysis catalyzed by esterase-related peptidases. Laying a selection pressure on oxidation, for instance, by heavy use of piperonyl butoxide-synergized pyrethroids may drive evolution towards heavier reliance on hydrolysis. This implies one type of possible cross-resistance between insecticides.

Detoxified by	Oxidation	Hydrolysis
Malathion	x	X
Resmethrin	X	X
Etofenprox	X	
BTI		Special X
Temephos		X
Spinosad	X	
Methoprene	X	X

The table below shows the molecular target sites for insecticides used for mosquito control in New Jersey. It’s a good idea to rotate these insecticides to avoid resistance evolution by target site mutations, a more difficult type of resistance to overcome than metabolic resistance.

Insecticides	Mode of action
Malathion	Nerve: acetylcholinesterase inhibitor
Resmethrin	Nerve: sodium channel interference
Etofenprox	Nerve: sodium channel interference
Bti	Cell membrane destruction
Temephos	Nerve: acetylcholinesterase inhibitor
Spinosad	Nerve: acetylcholine receptor
Methoprene	Juvenile hormone agonist

If pyrethroids or synergized pyrethroids must be used, the NJAES recommends the continued use of resmethrin-containing Scourge® for as long as it is commercially available. All pyrethroids are potential endocrine disruptors and should be used sparingly and with appropriate precautions.

For any application of an insecticide by a mosquito control professional, including any pesticide application in public places, the applicator or the direct supervisor must be certified and licensed as a “Commercial Pesticide Applicator” by the NJ DEP PCP Bureau of Pesticide Operations (N.J.A.C. 7:30-6). The correct license category is Category 8B - Mosquito Control. The Category 8C – Campground Pest Control license may be appropriate under certain circumstances. Pilots applying insecticides to control mosquitoes must have Category 11 - Aerial Pest Control in addition to 8B - Mosquito Control. The same holds true for research and demonstration applications, Category 10 - Demonstration and Research Pest Control and 8B - Mosquito Control are required. Training manuals may be obtained from your local county cooperative extension office. Certified and licensed applicators may have employees applying insecticides using non-aerial equipment under their direct supervision provided that these employees are registered as “Commercial Pesticide Operators” (N.J.A.C. 7:30-5). Contact the New Jersey Department of Environmental Protection, Pesticide Control Program (www.pcpnj.org) in Trenton for additional information regarding pesticide applicator permit details, 1 609 984 6614.

Common names of insecticides (along with Trade Names®) are used in the interest of increasing the understanding of the materials used. The trade or brand names given herein are supplied with the understanding that no discrimination is intended (against similar products not mentioned) and no endorsement by the New Jersey Agricultural Experiment Station is implied.

CONVERSION FACTORS AND ABBREVIATIONS

To aid in the use of the metric system, the rates and dilutions in these recommendations are given in the metric system units with the United States equivalent in parenthesis. Below is a list of the conversion factors and abbreviations used in these recommendations:

1 kilogram, kg = 2.2 pounds, lbs	1 fl ounce, oz = 29.6 mL
1 gram, g = 0.002 lbs	1 lb/acre = 1.12 kg/ha
1 hectare, ha = 2.47 acres	1 pint/acre = 1.17 L/ha
1 liter, L = 1.056 quarts	1 quart/acre = 2.34 L/ha
1 milliliter, mL = 0.001 L	1 fl oz/acre = 73.2 mL/ha

active ingredient (AI); aqueous suspension (AS); emulsifiable concentrate (EC); extended release (XR); kilometer per hour (kph); international toxic units (ITU)

LARVICIDAL APPLICATIONS

The following insecticides are recommended for the control of larvae of nuisance and vector species in various larval habitats. The insecticides are listed alphabetically, not in order of expected efficacy.

A. Catch basins

(1) Temephos (Abate®) emulsion or 5% extruded pellets according to product label.
(2) S-methoprene (Altosid®, Aquaprene®) pellets and standard briquets according to product label.
(3) Monomolecular films (Agnique®MMF, Golden Bear Oil, *i.e*. Mosquito Larvicide GB-1111®) as a larvicide/pupicide, according to product label.
(4) *Bacillus thuringiensis israelensis* serotype H-14 (BTI) briquets or other formulations, including Aquabac®, Teknar®, Vectobac®12AS, Bactimos® (see B3).
(5) *Bacillus sphaericus* (BSP) (see C4), including Vectolex® WSP (7.5% BSP) water-soluble pouch for use in catch basins.
(6) Spinosad (Natular®) XRG multiple-brood extended release granules, according to product label.

B. Fresh flood water areas, woodland pools

(1) Temephos (Abate®) emulsion, granules, 5% extruded pellets according to product label.
(2) S-methoprene (Altosid®, Aquaprene®) liquids, pellets, or briquets (standard) according to label.
(3) BTI (Vectobac®) according to manufacturer's directions. BTI must be ingested to be toxic and is therefore toxic only to actively feeding mosquito larvae. The active ingredient in BTI formulations (*e.g*., flowables, briquets, granulars, and pellets) may vary and is given as a percent (11.6% in Vectobac®12AS) and represented as International Toxic Units (ITU) per mg. Where such formulations are meant to be suspended in water for application, agitation must be provided to insure uniform application.
(4) Spinosad (Natular®) EC or G single-brood liquid or granules, according to product label.

C. Polluted and/or impounded waters

(1) Temephos (Abate®) emulsion, 1 or 2% granules, 5% extruded pellets according to product label. See also E3.
(2) S-methoprene (Altosid®, Aquaprene®) liquids, pellets, briquets (standard) according to label.
(3) Monomolecular films (Agnique®MMF, Golden Bear Oil, *i.e*., Mosquito Larvicide GB-1111®) as a larvicide/pupicide, according to product label.
(4) BSP recommended for the control of *Culex* larvae: use according to manufacturer's directions. BSP may also be an effective larvicide for non-Culex species.
(5) Spinosad (Natular®) XRG multiple-brood extended release granules, according to product label.

D. Prehatch for woodland pools with a record of annual early larval activities

(1) S-methoprene (Altosid®, Aquaprene®) pellets briquets (standard) according to product label.
(2) BTI briquets, according to product label.
(3) Spinosad (Natular®) EC or G single-brood liquid or granules, according to product label.

E. Salt marsh

(1) The use of larvicides on the open tidal marsh should be in conjunction with a plan involving water management for long-term reduction of the mosquito problem and of insecticide use. Heavy rains or exceptionally high tides may make it necessary to reapply larvicides in defined areas.
(2) Temephos (Abate®) 2% or 5% granules, emulsion, in sufficient water to accomplish efficient distribution at rates according to product label.
(3) S-methoprene (Altosid®, Aquaprene®) (see B2).
(4) BTI (see B3).
(5) Spinosad (Natular®) EC or G single-brood liquid or granules, according to product label.

F. Fresh water marsh

(1) Temephos (Abate®) (see B1).
(2) S-methoprene (Altosid®, Aquaprene®) (see B2); liquids, pellets, briquets (standard) according to product label.
(3) BTI (see B3).
(4) Spinosad (Natular®) EC or G single-brood liquid or granules, according to product label.

SPECIFICATIONS, FORMULATIONS and DILUTIONS for LARVICIDES

Emulsifiable concentrates

These formulations, which are to be diluted with water prior to spraying, may contain a small percentage of volatile solvent.

Dilution of concentrates

Temephos (Abate®) emulsions are prepared from a 4E concentrate 0.48 kg/L (4 lbs/ gallon). For most larviciding, dilute 36.6 mL in 93.5 L water/ha (0.5 fl oz in 10 gallons water/acre). For waters high in organic matter content, the concentration may be increased 2-3 fold.

Granular larvicides

All granular formulations should be formulated to insure efficient release of the insecticide in water. Temephos (Abate®) granules may employ carriers such as sand, celatom, Plaster of Paris, or Biodac® (a cellulose product); inclusion of an oil solvent does not appear necessary. S-methoprene (Altosid®, Aquaprene®) carriers include Plaster of Paris and Biodac®. No highly volatile solvents should be used in granular formulations. For celatom carrier, the optimum particle size for aircraft application is 24/48, with no more than 15% above 48 mesh, to minimize drift. For ground application, 30/60 to 60/80, depending on equipment, is optimum; more than 10% (by weight) in particles outside these specified size ranges is considered unsatisfactory.

PUPICIDAL APPLICATIONS

The pupal stage is the briefest stage in the development of the mosquito. As pupae are unaffected by organophosphates, pyrethroids, and other nerve poison type insecticides, BTI, or S-methoprene, there are few effective pupicides. These agents will also control fourth instar larvae, which may be present when it is necessary to pupicide. As with larviciding, timely efforts to control concentrated populations of pupae can be of value in preventing the emergence of adult mosquitoes and reducing the need to adulticide. The following type of insecticide is recommended for the control of pupae of nuisance and vector species.

- Monomolecular films (Agnique®MMF, Golden Bear Oil 1111, Bonide Mosquito Larvicide) according to product labels.

ADULTICIDAL APPLICATIONS

While the control of mosquitoes is generally most efficiently accomplished in the immature stages, conditions may sometimes necessitate the use of adulticides. If agencies other than county mosquito control commissions or agencies responsible for mosquito control wish to adulticide, they should contact the NJ Pesticide Control Program (609-984-6666) concerning regulations. Community or area-wide notification of adulticiding is required according to NJAC 7:30-9.10 (www.pcpnj.org).

Particular attention should be given to temperature, as it may affect droplet behavior, and the toxicity of the insecticide to the target mosquito. Of the types of adulticide recommended, the organophosphate malathion has a positive temperature coefficient, *i.e.,* more toxic at higher temperatures; resmethrin and other pyrethroids have a negative temperature coefficient, *i.e*., they are more toxic at lower temperatures. Ambient temperature, therefore, can influence the selection of insecticide.

The New Jersey Agricultural Experiment Station recommends the following adulticide measures. Synergized pyrethroid formulations (Scourge®, Anvil®, Duet®) should be used as rarely as possible and not over large contiguous areas to avoid or delay insecticide resistance evolution in local populations. Synergized pyrethroid formulations are most appropriately used only for barrier treatments.

A. Adulticiding with ground equipment

1. Thermal aerosols, fogging

Insecticide fogging can be an effective method in mosquito control. It is not meant to be used routinely but only when populations of adult mosquitoes reach public health or nuisance levels. These levels are highly variable and depend on the mosquito species involved as well as local environmental conditions. The final decision to fog should rest with the mosquito control professionals in each county. Trained personnel at these institutions are expertly knowledgeable about local mosquito populations and conditions. When fogging is deemed necessary, the following physical conditions, mostly encountered in the early evening and morning hours, should exist:

a. Air temperature: 15°C or higher (60°F)
b. Light intensity: below 20 foot candles, with light meter
c. Wind velocity: 5-8 kph (3 to 5 mph)
d. Stable thermal conditions to allow the fog to travel at ground level.

The only material recommended for fogging is malathion. The 95% malathion concentrate should be diluted as follows for fogging: 15 L (4 gal) concentrate is added to sufficient solvent to make 379 L (100 gal) final volume (0.4%). The diluted material is applied at a flow rate of 151 L/h (40 gal/h) with a vehicle speed of 8 kph (5 mph). An experienced and knowledgeable operator and a properly equipped vehicle and fogger are absolutely essential.

Per label, attention should be given to the flash point of the solvent used as measured by the “closed cup” method.

2. Sprays by mist blowers and hydraulic sprayers

While mainly intended for use with residual insecticides, this equipment can be employed to apply dilute emulsions of the non-persistent insecticide malathion to foliar surfaces for short-term residual mosquito control. The materials should be diluted and applied according to label recommendations for such equipment.

3. ULV (ultra low volume) spray applied by ground equipment

The technique of ULV has the advantage over fogging of being less dense and, therefore, less hazardous in urban traffic. Physical conditions as stated for fogging are generally desirable, and application should coincide with times of maximum adult mosquito activity in order to achieve maximum efficiency.

The technique of ULV employs more concentrated insecticides and the equipment for their application must be properly calibrated and serviced. Ground ULV applications do not always penetrate dense foliage as well as do fogging applications. Application of any ground ULV material should be performed under conditions also known to be best for efficient fogging operations (A1 above); wind speeds up to 16 kph (10 mph) are acceptable. Application should be made after sunset or before sunrise at temperatures of 15 to 28°C (60 to 82°F).

(a) Malathion (Fyfanon®, Atrapa®, 96-98%) at the flow rate of 90 mL/min at 16 kph or 45 mL/min at 8 kph (3 fl oz/min at 10 mph or 1.5 fl oz/min at 5 mph). With a constant volume flow meter and depending on conditions, *e.g.*, acreage to be treated and period of mosquito activity, application may be made at 20 mph. According to the labeling of these products, their application by ground ULV is restricted to professional mosquito control personnel who have the experience, knowledge and equipment necessary to follow the technical instructions for their use.

(b) Pyrethroid/piperonyl butoxide mixtures such as Scourge® (resmethrin/piperonyl butoxide in a 1:3 ratio), Anvil® (d-phenothrin/piperonyl butoxide 2+2) or Duet® (d-phenothrin/

prallethrin/ piperonyl butoxide – 5/1/5). Scourge® (4 +12) is available in a formulation for use without further dilution. Use these products according to instructions on the label and as seldom as possible.

B. Adulticiding by aircraft

Application from aircraft may only be performed according to Federal Aviation Regulations, by the county mosquito control commissions, equivalent county units, or the State Mosquito Control Commission using materials specifically labeled for application by aircraft (N.J.A.C. 7:30-6.3). To insure that the droplets descend from the aircraft to the areas of mosquito activity, these applications should be made close to sunset or thereafter, or early morning, when a deep temperature inversion occurs. For further discussion of this aspect see A. V. Havens, *Proc. N. J. Mosq. Ext. Assoc*., **60:**59-63 (1973).

1. LV (low volume) spraying

(a) 148 mL of 96-98% malathion per 2.3 L of No. 2 fuel oil/ha (2 fl oz 95% malathion in 1 quart of solvent/acre) (EPA SLN No. NJ-950003).

(b) Etofenprox (Zenivex® E20, requiring dilution or Zenivex® E4, ready to use) according to manufacturer's directions.

2. ULV (ultra low volume) spraying

(a) 220 mL/ha (3 fl oz /acre) of 96-98% malathion as applied by fixed wing aircraft or helicopter equipped with a rotary atomizer (*e.g*., a Beecomist nozzle) according to insecticide manufacturer's specifications with the additional stipulation that wind velocity be no greater than 8-16 kph (5-10 mph). To insure that the equipment performs correctly and produces proper droplet sizes, the equipment should be periodically calibrated and examined closely. Systems should include elements for positive shutoff of delivery. Spray droplet size should be determined periodically. To prevent malfunction of the system, the malathion should be filtered just prior to use by a method similar to that described by H. R. Rupp, *Mosquito News*, **33:**463-464 (1973).

(b) Resmethrin/Piperonyl butoxide in a ratio of 1:3 by weight, such as Scourge® at rates according to the label.

(c) Etofenprox (Zenivex® E20, requiring dilution or Zenivex® E4, ready to use) according to manufacturer's directions.

INSECTICIDE FORMULATIONS UNDER OBSERVATION FOR USE IN NEW JERSEY

Several other released materials could be useful for mosquito control in New Jersey. They have not yet been fully investigated for suitability. We recommend that exploratory applications be performed with the following:

- Anvil® (d-phenothrin 10% + PBO 10%) for ground or aerial adulticiding
- Aqua-Reslin® (permethrin 20% + PBO 20%) for barrier treatments
- Duet® (d-phenothrin/ prallethrin/ piperonyl butoxide – 5%/ 1%/ 5%)

Applications of these materials should be relatively small-scale and employ a variety of measurements of effectiveness, *e.g*., caged mosquitoes, light trap counts, or landing counts. It would also be of interest to make qualitative observations of possible effects on non-target organisms. NJAES relies on results from experimental applications to use for decisions of the inclusion of these materials in the recommended insecticides.

PRECAUTIONS AND SAFETY

Most insecticides are not only toxic to mosquitoes but can also be toxic to humans and other forms of life in the environment. It is necessary for all persons responsible for the use of insecticides to recognize this and take precautions to insure that these chemicals not only do not cause human illness or death but also absolutely minimally contaminate the environment. Further information is available from the National Pesticide Information Center (1 800 858 7378 or at npic.orst.edu). Public notice about planned spray operations must be issued according to NJAC 7:30-9.10 (www.pcpnj.org).

Manufacturers are required by law to list on the insecticide label those precautions to be followed to reduce hazards. Such precautions include not only appropriate concentrations to be used but also protective clothing for applicators, antidotes for poisoning, and conditions of storage.

Precautions should also be taken at other times. Insecticides should be stored in a manner inaccessible to people who are not knowledgeable of their toxicity and hazards. Storage should be in an area set aside solely for that purpose, and the area should be well ventilated to prevent overheating and subsequent noxious fumes of solvents or insecticides. When empty, insecticide containers should be triple rinsed, punctured and disposed of according to the product label, or returned to the supplier. Containers should not be burned because of air pollution by smoke and residual insecticide in the containers. Unused insecticides should not be discarded in drainage systems but should be turned over to authorized agencies for appropriate disposal. Regulations for storage can be found at NJAC 7:30-9.5 and 9.6, and general regulations on disposal are at 7:30-9.7. More specific requirements and guidance for the disposal of waste are available from NJ DEP PCP at 1 609 530 4070 or www.pcpnj.org or from NJDEP at 1 877 927 6337.

NEW JERSEY POISON INFORMATION AND EDUCATION

During the mixing and application of insecticides, all precautions listed on the insecticide labels should be followed. We recommend establishing background acetylcholinesterase activity levels by the appropriate test in all personnel working with organophosphate insecticides, during periods of extended use, and periodically thereafter. For information and aid regarding acute insecticide poisoning, call either the NJ Poison Information and Education System, 1 800 222 1222; http://www.njpies.org or the National Pesticide Information Center, 1 800 858 7378; http://npic.orst.edu/ . Please consult available web sites for extensive information on safety and other aspects on insecticides.

NEW JERSEY POISON INFORMATION AND EDUCATION SYSTEM
1 800 222 1222
or
[www. njpies.org](www.njpies.org)

COMMON NAMES AND PROPRIETARY EXAMPLES

Common name	Proprietary examples®
Bacillus sphaericus (BSP)	Vectolex
Bacillus thuringiensis israelensis (BTI)	Bactimos, Teknar, Vectobac, Aquabac
Ethoxylate surfactant	Agnique MMF
Malathion	Fyfanon, Atrapa
S-Methoprene	Altosid, Aquaprene
Permethrin/piperonyl butoxide	Aqua-Reslin
Petroleum derivative	Mosquito Larvicide GB 1111
d-Phenothrin	Sumithrin
d-Phenothrin/piperonylbutoxide	Anvil 10+10,
d-Phenothrin/ prallethrin/ piperonyl butoxide	Duet
Resmethrin/piperonyl butoxide	SBP-1382, Scourge
Spinosad	Natular
Temephos	Abate

APPENDIX

"Best Management Practices for Mosquito Control in New Jersey"*

OVERVIEW OF MOSQUITO CONTROL IN NEW JERSEY

New Jersey has a diverse ecology that provides habitat for more than 60 species of mosquitoes. New Jersey also has more human residents per square mile than any other state. At the turn of the 20^{th} century, New Jersey functioned as the center for mosquito research and the early (http://www-rci.rutgers.edu/~insects/wiab.htm) workers developed many of the basic concepts used in mosquito control today. Their successes led to the creation of organized, multidisciplinary mosquito control as a proper function of government. Information sharing among researchers and control workers was recognized as an important component of responsible mosquito management and was formalized in the early 1900's.

The philosophy of mosquito control in New Jersey is to target mosquitoes and/or their habitat as specifically as possible in a financially efficient manner. Minimizing insecticide impact on non-target organisms has always been vital to public acceptance and was incorporated into the goals of the mosquito control community. The need to be specific in the selection and application of insecticides is fundamental to the methods we use in New Jersey.

The sanitation and habitat modification procedures developed or enhanced by the early mosquito control workers in New Jersey form the foundation for today's source reduction activities. The water management techniques pioneered by New Jersey's early workers have been honed into the most efficient long term methods available today to reduce mosquito production. Enhancement of natural predators was deemed important in the early days of mosquito control and is now an accepted component of New Jersey's program that is funded and coordinated by our state agencies.

Surveillance is one of the best tools we have for focusing mosquito control on specific pest and vector species. Sampling and identification allow problem species to be recognized and targeted for control. Early mosquito control workers in New Jersey benefited greatly from the landmark investigations of John B. Smith (http://www-rci.rutgers.edu/~insects/early.htm), a legendary taxonomist and founder of organized mosquito control. Surveillance programs to monitor disease organisms and their mosquito vectors were not available to early workers but are fundamental to New Jersey's programs today. In New Jersey, the need for control, type of management employed and alternatives to insecticides are all weighed against the surveillance data we collect.

The history of mosquito control in New Jersey shows long standing environmental awareness and the ability to select insecticides, only when necessary, from the broad array of techniques we have at our disposal.

NEW JERSEY'S CONCEPT OF A RESPONSIBLE MOSQUITO CONTROL PROGRAM

Mosquito control in the state of New Jersey is mandated by law under Title 26, Chapters 3 & 9 of the NJ Health Statutes.

Title 26 assigns the control of pest and vector species to county mosquito control commissions which function as autonomous units of county government. Activities and expenditure of funds are overseen by a body of commissioners appointed by the board of chosen freeholders in each county. Tax levies provide the operational budget on a county-by-county basis. Autonomous mosquito commissions have the powers of a local board of health regarding mosquitoes including the right of entry onto public and private properties. They have the power to make a declaration regarding mosquito nuisance and can issue an abatement notice whenever necessary. Seven New Jersey counties currently maintain autonomous commissions and 14 counties have mosquito control responsibilities assigned to other agencies of county government.

The laws enacted by Title 26 mandate the Director of the NJ Agricultural Experiment Station (NJAES) at Rutgers University to function in an advisory capacity to all mosquito control agencies in the state. Specific duties of the Director include: 1) annual review of mosquito commission plans & estimates, 2) conducting surveys for county agencies upon request, 3) investigating the life histories of individual species, 4) recommending methods for control, and 5) conducting extension related activities that educate the public and advocate responsible mosquito control. A primary objective of NJAES involvement in Title 26 is to maintain professionalism within the mosquito control community in New Jersey that is consistent with current environmental concerns.

Title 26 also provides for a State Mosquito Control Commission (SMCC) that functions in an advisory capacity to the Governor. Composition of the SMCC includes 6 public members appointed by the Governor and representatives from the New Jersey Department of Environmental Protection (NJDEP), the NJ Department of Health and Senior Services (NJDHSS), the NJ Department of Agriculture (NJDA) and the NJAES. The SMCC is mandated to carry on a continuous study of mosquito control operations in the state, recommend the amounts of money deemed necessary for mosquito control purposes and allocate state aid to counties from an annual appropriation. The Office of Mosquito Control Coordination (OMCC), within the NJDEP, administers SMCC funding and expedites operational programs advocated by that body. Representation of the above mentioned departments of state on the SMCC board fosters a network of communication that recognizes the interdepartmental nature of mosquito control problems and activities in the state.

The operational aspects of mosquito control in New Jersey are conducted by the autonomous mosquito control commissions described above, mosquito control agencies within other county departments as well as federal, municipal and private mosquito control programs. Regardless of the agency, the NJMCA advocates the following as necessary components of responsible programs.

A. SURVEILLANCE. NJ believes that mosquito control begins with a surveillance program that targets pest and vector species and justifies the need for control. We believe that species-specific records should be kept on the composition of mosquito populations prior to enacting control of any kind. We also advocate records on the composition of mosquito populations after management to determine the effectiveness of control operations. The New Jersey light trap was designed as a surveillance tool more than 50 years ago for that purpose. Most mosquito control agencies use light traps in their programs but have additional tools that provide data to guide their activities. The following list of surveillance methods is available for use by mosquito control agencies in New Jersey.

1. Larval Surveillance. Larval surveillance involves sampling a wide range of aquatic habitats for the presence of pest species during their developmental stages. Most counties have a team of inspectors to collect larval specimens on a regular basis. A mosquito identification specialist normally has the task of identifying the larvae to species. Properly trained mosquito identification specialists can separate mosquito species that cause nuisance and disease from those that are non-pests or beneficial species. Responsible control programs target pest populations for control and avoid managing habitat that supports benign species.

2. Adult Surveillance. Adult surveillance measures mosquito populations that have successfully developed and emerged from aquatic habitats. The New Jersey light trap has been the standard for collecting adult mosquitoes and most county agencies operate light traps from early May through October. Portable traps baited with carbon dioxide are useful in areas where electricity is not available. Not all mosquito species are attracted to light and other forms of adult surveillance are frequently employed, *e.g*., gravid traps. In coastal areas of New Jersey, 1-minute landing rates are used to assess the comparative size of host seeking salt marsh mosquitoes during daylight hours. At inland areas, 10-minute bite counts measure annoyance after dark. Resting boxes are frequently used to measure populations of *Culiseta melanura*, a bird-feeding mosquito that functions in the amplification of eastern equine encephalitis (EEE) virus. Bird-baited traps are sometimes employed to measure *Culex* mosquitoes that amplify St. Louis encephalitis virus.

3. Virus Surveillance. The New Jersey SMCC funds a virus surveillance program that estimates the size of virus vector populations during the summer season and tests specimens for virus presence weekly. Mosquito collections are made at permanent study sites by staff from the NJAES. A wide range of assistance and support is provided by local mosquito control agencies in this effort. Specimens are tested for virus at the NJDHSS and some county laboratories by immunoflourescent antibody and polymerase chain reaction (PCR) technology. In addition, some county mosquito control agencies run sentinel chicken programs to identify areas where mosquito-borne encephalitis virus is active and test mosquitoes for virus by PCR to keep their control activities current. The status of mosquito borne encephalitis virus is disseminated to all mosquito control agencies in the State in a weekly summary throughout the encephalitis season.

B. SOURCE REDUCTION. Source reduction is the alteration or elimination of mosquito larval habitat. This remains the most effective and economical method of providing long-term mosquito control in New Jersey. Source reduction can include activities as simple as the removal of used tires and the cleaning of rain gutters and bird baths by individual property owners, to extensive regional water management projects conducted by mosquito control agencies on state and/or federal lands. All of these activities eliminate or substantially reduce mosquito breeding and the need for repeated applications of insecticides in the affected habitat. Source reduction activities within New Jersey can be separated into the following two general categories:

1. Sanitation. The by-products of the activities of people have been a major contributor to the creation of mosquito larval habitats. An item as small as a bottle cap or as large as the foundation of a demolished building can serve as a mosquito larval habitat. Sanitation is a major part of all IPM programs exemplified by tire removal, de-snagging waterways, catch basin cleaning, and container removal.

Mosquito control agencies in New Jersey have statutory police powers that allow for due process and summary abatement of mosquito-related public health nuisances created on both public and private property. The sanitation problems most often resolved by agency inspectors are problems of ignorance, neglect, oversight or laziness on the part of property owners. Collectively, they result in a major use of agency manpower and resources.

Educational information including videos, slide shows and fact sheets distributed at press briefings, fairs, schools and other public areas have information regarding the importance of sanitation. We must continue to emphasize the role of sanitation as an effective mosquito control modality that is a cost effective, low tech, high result method of preventing disease potential and mosquito interference with our ability to enjoy the outdoors.

2. Water Management. Water management for mosquito control is a form of source reduction that is conducted in fresh and saltwater larval habitats.

a. *Freshwater Wetlands Management* - In 1987 the NJ State Legislature enacted into law the New Jersey Freshwater Wetlands Protection Act (NJSA 13:9b-1 *et seq*.) All ditch maintenance, stream and storm water basin cleaning, and/or restoration activities for mosquito control are now regulated by the NJDEP. *Best Management Practices for Mosquito Control and Freshwater Wetlands Management* (BMP) (NJMCA Proceedings, 2002, p.88) have been compiled through the cooperative efforts of the mosquito control community, the NJDEP and other state and federal environmental agencies. These practices are applicable to mosquito control activities in stream corridor wetlands, isolated freshwater wetlands, palustrine wooded wetlands, and storm water facilities. Using mosquito surveillance data and BMP's, New Jersey's mosquito control agencies now conduct water management activities in the state's freshwater wetlands under a number of different "statewide general permits" (*i.e*. GP-1, GP-7, GP-15) or individual permits when necessitated by the complexity of the project.

In the past, the absence of design and maintenance standards for storm water management facilities throughout New Jersey resulted in many of the facilities becoming major mosquito producers. In the late 1970's, a 4-year study of storm water facilities in New Jersey showed that due to poor design, construction and/or lack of maintenance, 67% of all basins surveyed contained mosquito larval habitat with some facilities found to be suitable habitat for up to 8 mosquito species.

In 1989, a storm water management facilities maintenance manual was produced by NJDEP. The manual is available to all developers, engineers and planning agencies statewide. This document contains specific guidelines and recommendations relative to design, construction and maintenance of storm water facilities and mosquito control ( ).

b. *Salt Marsh Water Management* - Control of the aquatic stage of the mosquitoes that are produced on New Jersey's tidal wetlands requires a complete understanding of tidal marsh ecology. Two water management techniques were developed in New Jersey to control salt marsh mosquito larval populations through the cooperative efforts of county mosquito control agencies, Rutgers University, the State Division of Fish, Game and Wildlife, the Environmental Protection Agency and the U.S. Army Corps of Engineers. These are Tidal Restoration of Salt Hay Impoundments (TRSHI) and Open Marsh Water Management (OMWM), practices that now serve as models for water management activities worldwide.

TRSHI (P. Slavin, J. Shisler,& F. Ferrigno, 1978. Current status of tidal restoration of salt hay impoundments for mosquito control in Cumberland County, New Jersey, NJMCA Proceedings, p. 214) involves the removal and/or modification of ditch plugs and other water control structures to permit daily tidal inundation to occur in salt hay impoundments. Salt hay farming was once a major industry in the Delaware Bay area of New Jersey with over 11,000 acres of salt hay impoundments located in the counties of Cape May and Cumberland. These impoundments created ideal conditions for the production of salt marsh mosquitoes and required repeated applications of insecticides each season to control the larval populations originating in the impounded areas. The daily tidal exchange as a result of TRSHI eliminates mosquito breeding and eventually restores the area to a productive salt marsh. Over 7,500 acres of salt hay impoundments in New Jersey have been restored using TRSHI. Although TRSHI is utilized extensively to control mosquito production in salt hay impoundments, the techniques are also applicable to control mosquito breeding in other impounded marshes.

Open Marsh Water Management was developed in New Jersey in the mid-1960s through the cooperative efforts of mosquito control and wildlife agencies. OMWM (K. W. Bruder, 1980. The establishment of unified open marsh water management standards in New Jersey, NJMCA Proceedings, p. 72.) standards have been established for use by county mosquito control agencies, which address how and where the technique should be implemented. OMWM is now the major source reduction technique used by coastal mosquito control agencies in New Jersey. OMWM has been found to effectively control mosquito production on salt marshes through a combination of biological control and habitat manipulation. Three basic alterations are employed in OMWM, the construction of: 1) permanent ponds, 2) pond radials and, 3) tidal ditches. The selective excavation of the ponds, pond radials, and ditches eliminate mosquito breeding sites and provide permanent habitat for mosquito-eating killifish. In areas where OMWM is practiced, pesticide applications are substantially reduced.

C. CHEMICAL CONTROL. When source reduction and water management are not feasible or sufficient, chemicals are carefully used to control both adult and immature mosquito populations. The chemicals used by New Jersey's mosquito control agencies comply with state and federal requirements, as well as recommendations provided annually by the NJAES. All pesticide applicators and operators in New Jersey are required to be licensed by the NJDEP. Judicious chemical control activities, as part of New Jersey's IPM approach to reducing mosquito populations, use the most appropriate products available to the professionals of the mosquito control community. Chemical treatments can be directed against either the immature or adult stage of the mosquito life cycle.

1. **Larviciding.** Larviciding, the application of chemicals to kill the immature stages of mosquitoes by ground or aerial treatments, is typically more effective and target specific than treating adults. The objective is to target the immature stages at the larval habitat before populations have had a chance to disperse. New Jersey's IPM approach to mosquito control emphasizes larviciding only when source reduction is not feasible. Larvicides are applied to fewer acres than adulticides because treatments are made to relatively small areas where larvae are concentrated as opposed to larger regions where adults are present. The larvicides used for mosquito control in New Jersey include: *Bacillus thuringiensis israelensis* and *Bacillus sphaericus* (bacterial larvicides), S-methoprene (insect growth regulator), temephos (organophosphate), and petroleum oils.

2. **Adulticiding**. Adulticiding is the use of chemicals to reduce adult mosquitoes by ground or aerial applications. Adulticiding is used when biting populations reach critical levels. In New Jersey, adulticides are commonly applied as an Ultra-Low Volume (ULV) spray in which the small amounts of active ingredient range from 0.0035 to 0.24 lb/acre. The adulticides are dispensed through properly maintained and calibrated equipment. Adulticides used in New Jersey include pyrethroids and malathion (an organophosphate).

3. **The New Jersey State Airspray Program**. This program was established by state legislation in 1949 to assist coastal counties in the control of salt marsh mosquitoes. This ongoing program is now coordinated through OMCC within the NJDEP. Over the past decade this program has integrated a number of newer management techniques to provide for a more environmentally sound approach to pesticide applications. Emphasis is now focused on larviciding and an increased reliance on biorational pesticides. Many of the changes in the airspray program philosophy have been fostered from relationships cultivated between NJMCA members and federal and state wildlife refuge managers.

D. BIOLOGICAL CONTROL. Biological control is the manipulation of natural agents and their by-products to control pest and vector species. Biological control is advantageous because it is generally host-specific with limited non-target effects. In New Jersey, fish are the primary biological control agent used to suppress mosquito populations. Predacious fish, typically *Gambusia* species, are reared and stocked in mosquito larval habitats.

For many years, individual county mosquito control agencies raised and released their own fish. In 1990, the State of New Jersey established a statewide mosquito fish program with a specific protocol for use. With annual funding from the SMCC, the program utilizes the existing resources of the Division of Fish, Game and Wildlife's staff, hatchery and other facilities. While originally designed for *G. affinis*, the program now offers other species for mosquito control including the fathead minnow, the freshwater killifish and two species of sunfish. The use of State resources has expanded the concept of predatory fish for biological mosquito control in New Jersey.

E. EDUCATION.

1. **Continuing Education**. Continuing education is directed toward operational workers to instill or refresh knowledge related to practical mosquito control. Training is primarily in safety, applied technology and requirements for our State's regulated certification program. Examples of continuing education include: the NJMCA Pesticide Training Program, State-mandated Right to Know training for hazardous substances, the Northeast Aerial Applicator's Conference, monthly meetings of the Associated Executives of Mosquito Control Work in NJ, the annual meeting of NJMCA and meetings of other mosquito control associations in our geographic area.

2. **Public Education**. Public education is designed to teach the general public mosquito biology and to encourage residents to use simple preventive sanitation techniques. Examples include: fact sheets and brochures, classroom lectures at schools, slide shows, films and videos on mosquitoes and their control, and exhibits at fairs. NJMCA regularly interacts with civic leaders, politicians and professionals through the annual conventions of the NJ Educational Association and the NJ League of Municipalities. NJMCA produces and distributes proceedings of its annual meeting and coordinates activities in support of the recently enacted national Mosquito Control Awareness Week. NJMCA believes that public education reduces homeowner insecticide applications and the general misuse of toxic materials. Public education encourages support for organized mosquito control rather than crisis management, which relies heavily on insecticides.

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