MOSQUITO CONTROL IN MINNESOTA: TECHNIQUES USED IN METROPOLITAN AND RURAL PROGRAMS

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ABSTRACT. This detailed presentation of the *Aedes* mosquito problem in Minnesota includes a discussion of the environmental factors which contribute to the state's high mosquito population levels, the species faunal diversity and biology as it influences the control programs, and the current urban and rural control methodology. Emphasis is placed on the role of physical, biological and chemical control measures as they are applied in the Minneapolis-St. Paul metropolitan area.

Mosquitoes are produced in Minnesota by climatic factors rather than man's activities. Accordingly, the year to year fluctuations in mosquito populations are predicated on the amount of annual precipitation received. Currently, organized mosquito control is confined to the metropolitan Minneapolis–St. Paul area due to the high cost of larval control measures, the low tax base of rural communities and the requirement that a control program cover a large enough area to provide a buffer against the 10–15 mile flight range of the principal pest, *Aedes vexans*. Rural communities and resort areas commonly conduct adult mosquito measures on an as-needed basis using thermal and non-thermal aerosol machines, mist blowers or power spraying equipment to apply contact or short term residual treatments. In most instances however the control achieved is less than desired, and rapid reinfestation restricts outdoor activity to the daylight hours.

The topography of the eastern half of Minnesota reflects the impact of the past glacial activity which has produced undulating land favorable to the formation of a large number of marshes and lakes. An average of 18 in. of rainfall is received during the mosquito season. Surface runoff from summer thunderstorms collects in intermittent water depressions which hold water after each rain of 1½ in. or more for the 7 to 10 days required for *Aedes* mosquito development. In contrast to other areas of the United States, streams play a minor role in surface run off. Thus the undulating land and summer rains are the principal reasons for the State's serious *Aedes* mosquito problem.

The Metropolitan Mosquito Control District was formed in 1958 as a cooperative 6-county agency to conduct mosquito control within its 2,633 mi^2 area. An initial 50¢ per capita tax rate was set by the Legislature based on the cost to make one aerial treatment for the control of forest tent caterpillars in northern Minnesota during the early 50's. This rate was unrealistically low in relation to the extent of the mosquito problem which involves approximately 21% of the total area. The current cost of \$1,710/mi^2/year is dictated by present control technology and the average of 25 breeding sites totaling 135 acres/mi^2. The 1976 \$.80 per capita tax funds larval control measures over a 900 mi^2 area.

The mosquito fauna includes 50 species, 26 of which are univoltine or multivoltine *Aedes* species. The principal univoltine spring *Aedes* or woodland mosquito species are *Ae. stimulans, Ae. sticticus, Ae. fitchii, Ae. abserratus* and *Ae. excrucians.* This group accounts for 21% of the mosquito annoyance experienced by residents.

The primary multivoltine *Aedes* species are *Ae. vexans, Ae. cinereus, Ae. dorsalis, Ae. trivittatus* and *Ae. triseriatus.* The major summer pest species *Ae. vexans* constitutes 70% of the season-long annoyance in the Metropolitan area. The extensive 10 to 15 mi. flight range of this species causes substantial infiltration of adult mosquitoes into the interior of the District covered by the larval control program.

The univoltine lake and marsh breeding mosquito *Mansonia perturbans* is a major pest species during its June 15 to July 31 emergence period. It is particularly troublesome to residents living near marsh habitats. No larval control measures are conducted against this species, due to the high dosage rates which would be required to achieve control.

The field control program begins approximately March 15 when early *Aedes* mosquito species begin hatching, and continues to approximately September 15 when *Ae. vexans* eggs enter diapause. Forty-two vehicles are owned by the District, and an additional 31 are leased each season. During the months of June through August two employee shifts work, one from 6:00 a.m. to 2:30 p.m., and the second from 2:00 p.m. to 10:30 p.m. This permits double use of equipment and makes possible evening aerosol applications. The District operates 56 non-thermal aerosol machines, 6 Leco machines and 50 units of a modified Butte County MAD design which were built by the District. All aerial applications are performed under contract by 2 helicopters each of which is equipped with 3 application systems. The systems include a Simplex granule spreader, a ULV 6 fl oz/acre larviciding and a 10 fl oz/acre high pressure atomization system for adulticiding. During the early season ULV larviciding applications are used until the vegetation canopy hinders control; granules are used for the remainder of the season. Larval breeding sites smaller than 3 acres are treated by ground, sites larger than 3 acres receive aerial treatment. Perimeter larviciding treatments are frequently used in sites larger than 50 acres when breeding is confined to the shallow margins. A 2-way radio repeater network is used to coordinate the field program.

A system of 35 rain gauges is monitored by field employees to determine which areas have received significant levels of rainfall following rain storms. Using this information and the experiences gained from past years, employees check indicator mosquito breeding sites in those portions of the District receiving rainfall to determine the magnitude of a brood hatch.

The entomology procedures over the years have included larval collections from each field mosquito breeding site. The species composition of each has been stored in a computer bank for reference purposes. Larval identifications are made prior to making treatments of ground sites if the species history is in doubt. The species composition is determined prior to making aerial treatments. Adult mosquito populations are determined by 16 light traps and day biting collections, the latter are used to guide the adult control measures. Adult flight activity levels prior to and during non-thermal aerosol applications are monitored to determine when the flight activity drops off at which time the control measures are discontinued.

The criteria for the use of insecticides in the District larval control program are set forth in a key format titled "Guidelines for Larval Mosquito Control Measures" (Table 1). As indicated in this key, Abate is used in the areas in which runoff could enter into lakes. These sites constitute approximately 25% of all mosquito breeding areas within the District. Depressions which collect rain water from intermittent summer rain storms and do not drain into lakes or streams are controlled with Dursban. These dead-end depressions constitute approximately 75% of all mosquito production areas and are the most productive in terms of the number of adult mosquitoes produced per yd^2 of water surface. Control measures are instituted following each rainfall which accumulates sufficient water to permit larval development to be completed. Abate remains biologically active in treated sites for 12 to 24 hours after application, whereas Dursban provides control for 40 to 50 days during the spring at .05 lb AI/acre and 18 to 40 days control when applied as a pre-hatch treatment at 0.1 lb AI/acre during the summer months. As new eggs hatch each time the water level rises, if a succession of storms occur during the mosquito developmental period, sites treated with Abate usually require treatment a second time, which reduces the number of sites which can be reached prior to adult emergence and thus fewer breeding sites are controlled.

Due to the infiltration of adult mosquitoes from the perimeter of the larval controlled area into the interior of the District, adult control measures are performed around parks, day camps, recreation areas, and outdoor public events which result in large gatherings. Small rural communities and outlying high density residential areas with high mosquito populations receive adult control applications when possible. Non-thermal aerosol applications of resmethrin are conducted during favorable windspeed, temperature and temperature inversion conditions. With the onset of a stable inversion, and wind speeds of less than 5 mph at temperatures above 60° F adult mosquito control applications are initiated 15 min after sundown when the peak mosquito flight activity commences. With a vehicle speed of 10 mph, excellent adult control has been achieved 500 ft downwind with resmethrin at 1.5 fl oz and .0035 lb AI/acre.

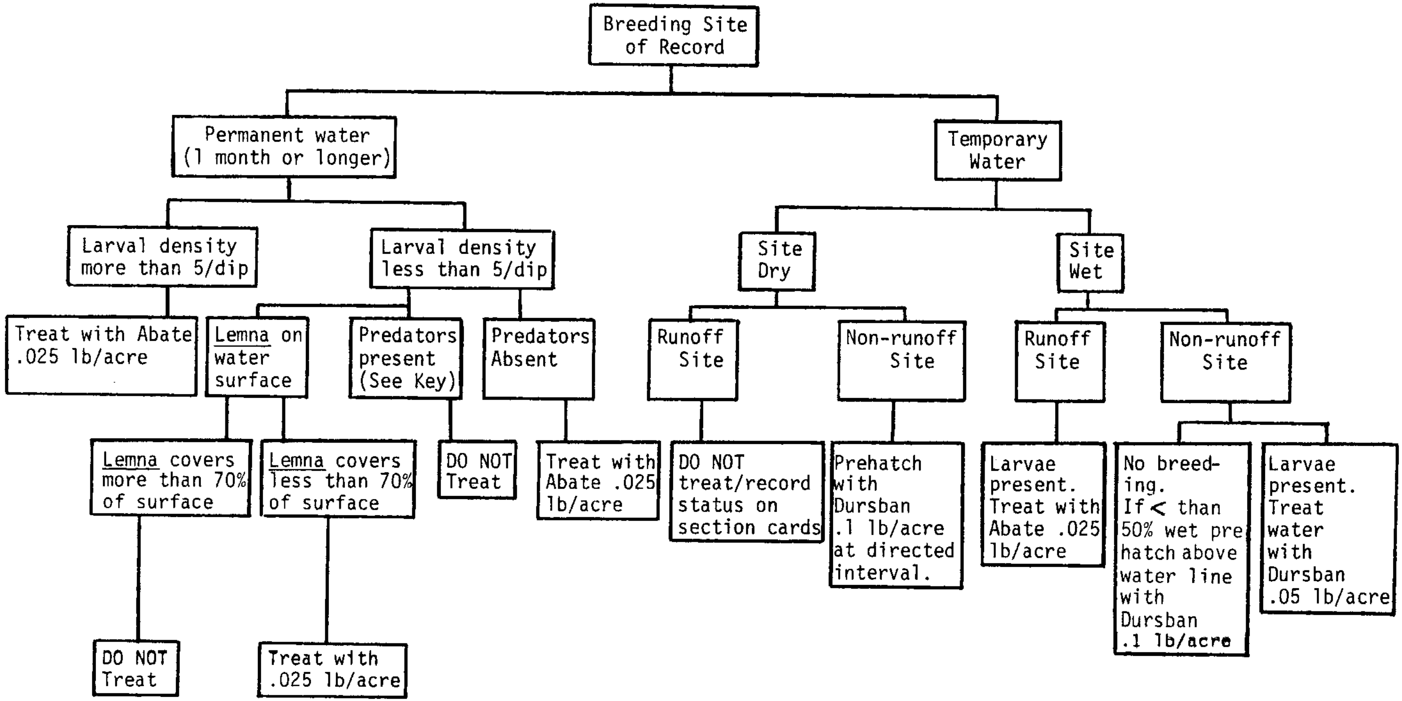
In the absence of a U. S. Environmental Protection Agency registration for malathion, pyrethrum or resmethrin applied by helicopter, Dursban used for adult control at .025 lb AI/acre applied with a high pressure adulticiding system (Mulla et al. 1973) at 10 fl oz/acre with a 320 ft swath has achieved excellent adult control.

In 1974, the need for long range planning to reduce the magnitude of the mosquito problem in the Minneapolis-St. Paul metropolitan area resulted in a reevaluation of the District program which gave greater emphasis to finding permanent solutions to the mosquito problem. Accordingly, goals were set forth in the

Table 1

METROPOLITAN MOSQUITO CONTROL DISTRICT

GUIDELINES FOR LARVAL MOSQUITO CONTROL MEASURES



areas of biological, physical and chemical control to develop information needed to use non-chemical methods in the operational control program.

In the area of biological control the goal is to use natural control agents to reduce mosquito production in permanent water mosquito breeding areas which lend themselves to control by introduction of predator populations via spring inoculative releases of mass cultured predators known to be effective in combination with each other, or integrated with compatible larvicide treatments at ppm levels approximating the larval LD_{50}–LD_{75} levels, which concentrate predator feeding on surviving larvae and reduce the insecticide impact on predators populations.

To achieve this goal, a 12-month study on the population dynamics of natural control agents of mosquitoes in 6 permanent-water mosquito breeding areas has recently completed the biweekly field sampling phase via the use of a quantitative water column sampler for insects in shallow aquatic habitats (Legner et al. 1975). Following the determination of the most effective native predators, work on the development of mass culture and storage methods for these organisms is planned.

In an effort to understand the basic physical and chemical relationships which contribute to the high mosquito populations levels in Minnesota, and to use this information to define and conduct a long range source modification program which is compatible with other environmental interests, factors influencing water percolation are being studied. It has been found that the temporary water depressions which produce most pest mosquitoes do so due to the impermeable dense layers which have formed from the colloidal materials transported by runoff waters. Studies the past 2 years have confirmed that it will be possible to prevent mosquito breeding in these locations for 15–20 years by a single treatment of an environmentally compatible, low cost, non-proprietary material which will increase the rate of water percolation permitting the site to dry prior to completion of mosquito development. Preparation of a manuscript on this work is in progress. Current estimates are that this approach will permit approximately 13,000 *Aedes* mosquito breeding sites to be eliminated and in the process reduce the mosquito annoyance levels 40% within 10 years.

A primary need in the area of chemical control is to develop a controlled release larvicide formulation which will provide extended control of *Aedes vexans* in areas which cannot be controlled by other means, to avoid the labor investment now required. In the fall of 1974, work began to develop a biodegradeable controlled release mosquito larvicide formulation, capable of achieving 2–3 months control of *Aedes* mosquito breeding areas, which can be manufactured by District employees during winter months. Recent laboratory evaluations of differentially crumbling silicate capsule formulations have produced extended release rate characteristics under laboratory conditions (Sjogren and Thies 1975; Schandle et al. 1976). Field evaluations during the 1977 season will be directed at obtaining efficacy data for EPA registration.

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