CONTROL OF *AEDES VEXANS* IN THE MIDWEST: CURRENT STATUS AND FUTURE NEEDS

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When Bill Rapp invited me to join a panel discussion on *Aedes vexans*, I enthusiastically accepted when I learned the purpose of the panel was to identify control needs and seek funding to provide answers to problems which hinder operational control programs.

I will speak from my experience with the Metropolitan Mosquito Control District (MMCD) program in the Minneapolis-St. Paul metropolitan area. With several exceptions, our program approach is typical of organized mosquito control agencies in the midwest.

The MMCD was formed in 1958 at citizens request, resulting in the union of 6 counties, totaling 2,633 square miles, to suppress mosquito populations on a regional basis. The environmental factors which contribute to the region's large mosquito populations include rolling topography which results in abundant intermittent water depressions, marshes and lakes. An average of 18 in. of summer rainfall is received each mosquito season, often from intense thunderstorm activity. Surface runoff from rains of 1½ in. or more remain for the 6–8 day period required for *Ae. vexans* larval development. In contrast to other areas in the United States, streams play a minor role in surface runoff.

The mosquito fauna includes 50 species, 26 of which are univoltine or multivoltine *Aedes*, with *Ae. vexans* the major summer pest species.

A total of 54,000 individual mosquito breeding sites are on record, encompassing 240,000 acres or 20 breeding sites, totalling 91 acres per square mile. Site density ranges from 0 to 140 per square mile. In suburban areas, residences are interspersed with intermittent water depressions, marshes, and woods to make them as desirable for residential development, as they are productive of mosquitoes.

Current annual MMCD resources of $1,800,000 provide a 15 mile control radius encompassing approximately 700 square miles, and 22,000 mosquito breeding locations. The larval control program cost approximates $2,500 per square mile per year.

Forty permanent and 120 seasonal employees, assisted by 2 helicopters, work a mosquito season from March 15 to September 15 to provide the maximum mosquito suppression possible for the greatest number of residents.

During the early years of the program a larval control buffer area was in effect around the metropolitan area. In recent years urban development has expanded to the point that an adequate buffer to reduce infiltration of mosquitoes into the urbanized region no longer exists. As a result considerable mosquito annoyance is experienced in suburban communities. Annual fluctuations in adult mosquito populations exist due to differential egg hatch with varying rainfall levels. Adults emerging beyond the 15 mi. control radius can readily move 2 to 6 mi. (up to 15 mi.) from larval breeding areas. The number of mosquitoes encountered depends upon the size of the mosquito brood and the distance inside the uncontrolled perimeter at which the measurement is made. As determined by 7 program effectiveness analyses conducted as part of an Environmental Impact Statement (Sjogren et al. 1977), the program achieves 87% control in the interior, 65% control at the 8 mi. radius and 43% just inside the perimeter of the larval-control area.

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[1] Presented at a Panel Discussion, AMCA Washington meeting, April 11, 1979.

CONTROL METHODS USED

The MMCD program emphasizes *Ae. vexans* larval control working from the center of the metropolitan area out in concentric zones. Rains of 1½ in. or more induce a larval brood, initiating a control cycle. The annual *Ae. vexans* season runs from May 20 to September 15 with an average of 6 broods, with a range of 3 in 1976 to 14 in 1975.

Section maps are used to indicate known mosquito breeding areas, and associated section cards record 14 data points on each inspection. A computer accesses long term control records, mosquito species occurrence and densities. The congested urban setting and frequent need to reload dictate the use of helicopters for aerial application. Sites smaller than 3 acres are controlled by ground crews; larger sites are controlled by air. Insecticide granules are used for both ground and air applications to reduce drift and aid penetration of vegetation.

Annual surveillance for insecticide resistance to temephos (Abate®), in use since 1958, and chlorpyriphos (Dursban®), in use since 1974, has shown no resistance to date. Temephos is used at 0.06 to 0.1 lb. AI/acre to control larvae in "sensitive sites" such as marshes, areas which drain into marshes, streams or lakes. It is also used until July in depressions which normally hold water until July, but which go dry thereafter.

Some of these areas develop aquatic insect and crustacean fauna, high in protein, needed by migratory and resident waterfowl. These birds require the protein to rebuild their body reserves following spring migration. The level of protein in the diet also influences the number of eggs laid during the nesting season (Swanson et al. 1974). As the nesting season is normally completed by the first of July, and the sites become intermittently wet and dry thereafter due to evapotranspiration, the sites are band-treated above the water line with chlorpyriphos after July 1. The prehatch treatment consists of a band-treatment above the water line if the site is wet, and across the bottom of the site up to the 50% wet level, if dry. Sites in basin depressions which do not drain out and produce *Ae. vexans* intermittently from summer rainstorms are prehatch treated with chlorpyriphos in the early summer at 0.05 AI/A and subsequently 0.1 lb AI/A during July and August. Malathion granules are used to control *Ae. vexans* in pastures.

A rain gauge network of 36 gauges, supplemented by a volunteer network of 200 observers reporting to the State Climatologist, is used to determine the distribution and quantity of rainfall.

Thus, the control sequence consists of chlorpyriphos prehatch of intermittant water basin sites until rainfall; emphasis is then placed on larval control in sensitive sites with temephos until brood emergence followed by return to prehatch. The prehatch cycle interval is dictated by loss of biological activity by the preceding application cycle.

Physical control through habitat modification is not emphasized in the program at the request of the Minnesota Department of Natural Resources. Efforts are confined to mosquito breeding locations which have been modified by human activities such as construction of ditches, freeway right of way depressions, etc.

Less than 10% of all the *Ae. vexans* breeding locations hold water permanently during the season and have water nutrient levels which support significant aquatic insect predator populations. Most *Ae. vexans* production areas are intermittently wet and dry; the name "floodwater mosquito" is appropriate. During each dry period, natural enemies are eliminated. Those marshes which are significant producers of *Ae. vexans* usually go dry in late summer preventing the overwintering of fish or predatory insect forms. In spring, when water collects in marshes and temperatures rise, predatory insects fly in to oviposit. By the time adequate populations of insect predators build up to impact on *Ae. vexans* broods, it is late June to mid July. This is within several weeks of the time the sites normally go dry again.

Control of adult *Ae. vexans* by nonthermal aerosol applications of resmethrin at .0035 lb. AI/A in food grade white mineral oil is confined to the following priorities: Community or group functions, park and recreation areas, day-camps in rural wooded areas, adult mosquito harborage areas (i.e. dense woods) adjacent to heavily developed urban areas, and occasionally rural communities beyond the larval control areas. Street fogging in residential areas is not conducted routinely, although it is needed in many suburban communities when *Ae. vexans* populations are large. Available funds are devoted to the control of the greatest number of larval breeding sites possible to achieve the greatest overall control. Adult mosquito control with current technology is highly effective and relatively inexpensive (Sjogren and Frank 1979). However, due to the extent of the developed metropolitan area a single ground application costs $110,000 at 25 cents per acre.

An innovative *Ae. vexans* control program combining localized larviciding with adulticiding is conducted in the midwest by Clarke Outdoor Spraying Company, Roselle, Illinois. Using techniques to predict influxes of *Ae. vexans* (Clarke and Wray 1967), nonthermal aerosol applications are used to suppress adult *Ae. vexans* populations entering communities from beyond the larval control perimeter which operates within and 1 mi. beyond community boundaries. Correlating adulticiding treatments with light trap counts, applications are made when adult populations exceed 20 female *Ae. vexans* per night maintaining an annoyance level of below 2 bites in 5 min.

CURRENT PROGRAM DEVELOPMENT NEEDS

Improving control levels, within existing mosquito control agency funding levels, can best be done by 2 means: by optimizing application procedures to reach and control more mosquito breeding sites and secondly technical innovations to reduce the need to re-visit each *Ae. vexans* breeding depression after each rain. Both require the best utilization of all facets of physical, biological and chemical control, continually "fine-tuning" the control program as new data become available. The problem is, little funding is being devoted to develop the answers to pressing needs of mosquito control programs. As you are all well aware, a large gap often exists between the data developed by academic and experiment station staff on promising new mosquito control techniques, and those which can be put into operational programs.

I will spend the remainder of my available time in this panel discussion, pointing out what I see as operational need to more fully implement "Integrated Pest Management" in operational mosquito control programs.

From the administrative side, rising costs are requiring more cost consciousness than ever before. We can't really afford to develop program needs by trial and error method, and most Boards of Directors are reluctant to employ staff competent to do the quality of work needed to develop the information necessary to advance programs. Two needs in this area are: for a control program simulation to establish the optimum larval treatment thresholds to use at increasing distances from the center of a control area, based on the flight range of *Ae. vexans*, the distribution of the human population and the acreage of breeding sites present. Assuming the region is divided into a series of concentric circles from the interior out based on human population distribution, control would be initiated from the interior out following each rain. A decision is needed depending on acreage, temperature and rainfall (i.e. larval densities present) on which larval thresholds (i.e. 0.1, 1, 10 etc. larvae/dip) to use in each ring to achieve the greatest control.

Theoretically to compensate for the extensive flight range of *Ae. vexans* one should start at a low threshold in the interior and increase the threshold gradually, ultimately reaching the highly productive areas which contribute far flying adults (Nayar and Sauerman 1969). The difficulty is, if the treatment threshold is set too low, the larval control measures will not reach out far enough to provide the buffer needed to prevent the rapid reinfiltration of adults from beyond the treated area. If too high a threshold level is set, enough low producing sites in the interior will be left to produce a background mosquito population well above the threshold of human annoyance. Administratively, what threshold levels should be set, in each larval control ring to be sure that the control measures instituted will result in the lowest level of mosquito annoyance?

A second need is to develop a computer model to permit the overlay of mosquito breeding sites, average larval densities produced in each site, travel time between sites, rainfall patterns for each storm, ground water levels (marsh sites), and available manpower to direct attention to sites which have the greatest potential to produce significant mosquito populations in the time afforded by the larval development period. In some instances, large percentage of the breeding sites may be dry, or in the process of drying, when inspected during mid and late summer in efforts to control the smaller percentage of wet highly productive sites.

From the biological side, I am indebted to Dr. Wm. Horsfall for his outstanding text contributing to the understanding on *Ae. vexans* (Horsfall et. al. 1973) and subsequent papers on oviposition niches (Horsfall et. al. 1975). An unpublished review of the literature up to 1966 on the biology of this species (Mulla and Chaudhury 1966, University of California, Riverside) has also been of value in understanding *Ae. vexans*. However, the economic importance of this pest species in North America and the increasing evidence implicating it in woodland foci of Western encephalitis virus (Horsfall et. al. 1973, Brust, University of Manitola, unpublished data) and its efficient role in dog heartworm transmission (Hendrix, University of Minnesota, unpublished) supports the need for increased research in the following areas to improve our control capability.

Further study of the population dynamics of *Ae. vexans* as envisaged by Pritchard et. al. (1978) to construct a life budget should be funded. A continuation of Dr. Pritchard's work altered by drought, yet resulting in a substantial contribution to our knowledge of the larval surviorship curve, would permit better understanding of the population dynamics of *Ae. vexans* under natural conditions.

While considerable work has been done on the colonization of *Ae. vexans* over the years (Gjullin et. al. 1950, McDaniel and Horsfall 1957, Horsfall and Taylor 1967, Taylor and Brust 1974) and others, colony maintenance requires manual copulation. If natural cage mating could be achieved, it would undoubtably stimulate much additional research on this species.

The study of chemicals to modify the behavior of *Ae. vexans* warrants research to lure host- or habitat-seeking adults into traps or localized areas treated with short term residual insecticide deposits. Successes in developing control programs based on the responses of insects of medical importance to attractants have been recorded (Mulla and Stains 1977, Mulla et. al. 1977, 1978). Due to the economic importance of mosquitoes and the potential of this environmentally compatible control approach, substantial research in this area is needed to identify and combine the active fractions to which mosquitoes respond during different physiological stages.

A significant contribution to the control of *Ae. vexans* in intermittent water locations appears to lie in the development of economical controlled release formulations and water soluble coatings to protect mosquito larvicides subject to rapid degradation under field conditions. The development of Dursban 10CR led the field; however, its high cost and the concern over public acceptance of the application of plastic as the carrier led to research on differentially crumbling silicate capsule formulations (Sjogren and Thies 1975, Schandle et. al. 1976) and more recently work by Dr. James H. Nelson, U.S. Army. The technology holds potential to formulate controlled release formulations of rapidly degradable compounds such as temephos and methoprene needed in operational programs under environmental conditions where the latter may be the insecticides of choice.

Where prehatch applications of rapidly degrading materials are desired without a sustained release capability, need exists for the development of a water soluble coating for existing quick release granule formulations, which would protect the insecticide yet release the material after 24 to 72 hr in water. In the typical *Ae. vexans* habitat, release would occur at a time when the water volume would be 50% or less of initial volumes enabling reduced application rates.

Investigations are also needed to explore the potential of incorporating feeding attractants in granular formulations to concentrate larval feeding in close proximity to chemical and biological insecticides. The successful implementation of this concept using insecticides with low vertebrate toxicity could enable reduced dosage rates permitting much needed cost savings and/or more extensive use of higher priced control materials.

Due to the influence of environmental and physiological conditions on response of *Ae. vexans* to light traps, correction factors are needed to standardize collection variation. Light traps are our best tool to indicate mosquito population fluctuations near the traps. In our reliance on light traps, we equate trap count with relative human annoyance in the region of the trap. We could use light trap results more accurately in our programs if each trap was standarized as to location, collection levels relative to human annoyance levels in nearby residential areas, relative humidity, temperature, wind, moonlight, etc. While this may appear to be more involved than necessary, once developed the environmental factors representative of area wide norms for each night could be plugged into a small programmable calculator by lab personnel and reported for each station over the region as a corrected value.

When one considers the relative ineffectiveness of present staff deployment practices, in part, based on light trap results compared with the cost of obtaining a more accurate index of adult *Ae. vexans* populations, this could be returned many times over by increased control effectiveness.

In conclusion, these are some examples of need in operational programs to better utilize IPM in mosquito control. Integrated Pest Management needs in agriculture are not met by farmers with their budgets, but by federal funding. If IPM needs are to be met in mosquito control, and they should be, commitments to fund more than a token level of research in mosquito control must remain a responsibility of the same federal agencies proclaiming the merits of IPM.

Literature Cited

Clarke, J. L. and F. C. Wray. 1967. Predicting influxes of *Aedes vexans* into urban areas. Mosq. News 27(2):156–63.

Gjullin, C. M., W. W. Yates and H. H. Stage. 1950. Studies on *Aedes vexans* (Meigen) and *Aedes sticticus* (Meigen) floodwater mosquitoes in the lower Columbia River Valley. Ann. of Entomol. Soc. Amer. 43:262–75.

Horsfall, W. R. and M. L. Taylor. 1967. Temperature and age factors in inducting insemination of mosquitoes (Diptera:Culicidae). Ann. of Entomol. Soc. Amer. 60:118–20.

Horsfall, W. R., R. J. Novak and F. L. Johnson. 1975. *Aedes vexans* as a flood plain mosquito. Environ. Entomol. 4:675–81.

Horsfall, W. R., H. W. Fowler, L. J. Moretti and J. R. Larsen. 1973. Bionomics and embryology of the inland floodwater mosquito *Aedes vexans*. University of Illinois Press. 211 pp.

Mulla, M. S. and G. S. Stains. 1977. Eye gnats pest and plague of mankind. "The friendly Coachella Valley salute." Proc. Calif. Mosq. and Vector Control Assoc. 45:205–9.

Mulla, M. S., Y. Hwang and H. Axelrod. 1977. Attractants for synanthropic flies: Chemical attractants for domestic flies. Journ. Econ. Entomol. 70:644–8.

Mulla, M. S., Y. Hwang, E. C. Loomis and H. Alexrod. 1978. Products of putrefaction and brewing odors that attract synanthropic flies. Proc. Calif. Mosq. and Vector Control Assoc. 46:70–3.

McDaniel, I. N. and W. R. Horsfall. 1957. Induced copulation of aedine mosquitoes. Science 125:745.

Nayar, J. K. and D. M. Sauerman. 1969. Flight behavior and phase polymorphism in the mosquito *Aedes taeniorhynchus*. Entomol. Exp. Appl. 12:365–75.

Pritchard, G., M. A. Enfield, J. D. Slater and P. J. Scholenfield. 1978. Studies on the population dynamics of *Aedes vexans* (Meigen) and other mosquitoes in temporary ponds in the Calgary region. Report submitted to the Minister of Environment of the Province of Alberta. 129 pp.

Schandle, V. B., R. D. Sjogren, C. C. Thies. 1976. Silicate capsule formulations for mosquito control. Proc. International Controlled Release Symposium at Akron, Ohio pp. 6.13–6.17.

Sjogren, R. D. and A. M. Frank. 1979. Effectiveness and cost of non-thermal resmethrin aerosols for control of *Aedes* mosquitoes in wooded areas. Mosq. News 39(3):597–604.

Sjogren, R. D., C. C. Thies. 1975. Preliminary evaluation of capsules containing a chitin synthesis inhibitor. Proc. International Controlled Release Symposium, Dayton, Ohio pp. 217–21.

Sjogren, R. D., J. P. Genereux and M. M. Genereux. 1977. Metropolitan Mosquito Control District Environmental Impact Statement: Options for Control to the Year 2000. Metropolitan Mosquito Control District, St. Paul, Minnesota. 800 pp.

Swanson, G. A., M. I. Meyer and J. R. Serie. 1974. Feeding ecology of breeding blue-winged teal. J. of Wildlife Management 38:396–407.

Taylor, B. W. and R. A. Brust. 1974. Laboratory mating of *Aedes vexans* (Diptera:Culicidae). Ann. of Entomol. Soc. Amer. 67(1):137–8.