Effectiveness of Mosquito Control

CHAPTER 4

The Metropolitan Mosquito Control District's (MMCD) mission is to "promote health and well being by protecting the public from disease and annoyance caused by mosquitoes, black flies and ticks, in an environmentally sensitive manner." The goals of the District's mosquito control efforts are to reduce regional populations of human-biting mosquitoes and black flies.[1] We asked:

- **Is the Metropolitan Mosquito Control District effective at reducing larval and adult mosquito and black fly populations?**

- **How does the District measure its effectiveness?**

To answer these questions we reviewed annual operational reviews and other reports on the District's activities, interviewed District staff, analyzed treatment databases, and talked with entomologists in state agencies and at the University of Minnesota.

Measuring the effectiveness of mosquito control programs is difficult because it is hard to predict what "would have been" without intervention. Results of District-sponsored studies on the overall effectiveness of mosquito control efforts have been inconclusive. Instead, the District has tested the effectiveness of insecticides and used results of those material efficacy tests to document the effectiveness of mosquito control.

Overall we found that most of the insecticides used by MMCD to kill larvae do not meet the District's goal of killing 95 percent of larvae. Methoprene products used to kill cattail mosquito larvae have performed the best (92 to 99 percent control), while the average control achieved with *Bti* granules ranged from 78 to 89 percent control in 1995-97. We have some concerns about the methods MMCD used to calculate the efficacy of methoprene products used to kill floodwater mosquito larvae. In 1996, the District conducted efficacy tests on the insecticides used to kill adult mosquitoes and estimated that the average adult mosquito reduction in treated sites was about 57 percent. In 1998, the District collected pre- and post-treatment adult mosquito counts from over 500 sites, which showed a 90 percent reduction in the number of adult mosquitoes after

1 Metropolitan Mosquito Control District, *1998 Budget*, 4; Metropolitan Mosquito Control District, *Self-Assessment of Performance, 1994*: 9, 13, 24.

treatment. However, we have some concerns about using these data to evaluate the effectiveness of adult insecticides.

HISTORY

The District has attempted to address questions of effectiveness since the 1970s.

The Metropolitan Mosquito Control District has a long history of attempting to address questions of effectiveness. In a 1977 Environmental Impact Statement (EIS), the District used adult mosquito population data collected using light traps to estimate that the District's larval control program reduced mosquito annoyance by 87 percent at the center of the District.[2] A Supplemental EIS estimated that people can tolerate slightly over two mosquito bites in a five minute period and used field trials to document the effectiveness of individual insecticides used by MMCD.[3] The District also sponsored studies on the public perception of mosquito annoyance in 1990 and on the prevalence of adult mosquitoes in the District in 1993, conducted biennial public opinion surveys since 1994, and sponsored internal studies on the effectiveness of insecticides used.

A 1994 report by an Environmental Quality Board Mosquito Control Technical Work Group recommended, among other things, that MMCD should clearly define its mission, goals, and objectives.[4] Later that same year, the District completed a self-assessment of performance in which it identified goals, performance objectives and measures, and plans for improving these measures in future years.[5] The District has not revised its 1994 self-assessment, although its annual operational reviews provided updated information on some of the performance measures contained in the self-assessment. The District should reexamine the performance measures in its 1994 self-assessment to see if any performance measures could be added in its annual operational review.

The Environmental Quality Board Work Group also recommended that MMCD initiate a process to study efficacy issues and establish an interagency panel to oversee these studies.[6] MMCD created the Interagency Panel on Metropolitan Mosquito Control District Effectiveness, composed of representatives from state agencies, with participation by representatives from local governments and environmental groups.[7] The panel met eight times between 1994 and 1996 to help MMCD develop methods to measure its effectiveness. The panel considered both objective, physical measures (such as insect counts) and people's perceptions as it

2 Metropolitan Mosquito Control District, *Final Environmental Impact Statement: Options for Control to the Year 2000*, 1977: 3, 199, ei-28 - ei-34.

3 Metropolitan Mosquito Control District, *Supplemental Environmental Impact Statement* [Draft], November 1986: II-6.

4 Environmental Quality Board, Mosquito Control Technical Work Group, *Final Report*, April 1994: 3.

5 Metropolitan Mosquito Control District, *Self-Assessment of Performance, 1994*, October 1994.

6 Environmental Quality Board, Mosquito Control Technical Work Group, *Final Report*, April 1994: 3.

7 The state agencies represented on the interagency panel included the departments of Agriculture, Natural Resources, and Transportation, the Pollution Control Agency, and the Office of Environmental Assistance.

attempted to determine if MMCD's mosquito control efforts actually reduced the numbers of biting insects and improved the quality of life in the Twin Cities.[8]

The Interagency Panel identified many measures such as weather, mosquito breeding habitat, people's behavior and perceptions, and costs that would be helpful in analyzing effectiveness. It also concluded that predicting what "would have been" without intervention would be difficult. The panel sponsored a focus group to gather information on people's perceptions of the mosquito problem and a project using geographic information system (GIS) technology to analyze and predict mosquito production from treated and untreated breeding sites for a particular rainfall event. In early 1996, following the District's budget reduction, the panel concluded that it had completed its charge to assist MMCD with developing methodologies and identifying resources and tools needed to measure its effectiveness and it turned over implementation to the District.

MOSQUITO CONTROL

The District's goal is to kill 95 percent of mosquito larvae or adults when it uses insecticides.

To achieve its goal of reducing regional populations of human-biting mosquitoes, the District treats breeding sites to kill mosquito larvae. It also sprays insecticides to kill adult mosquitoes as needed and requested.[9] To measure effectiveness the District evaluates the efficacy of the insecticides it uses to kill mosquito larvae and adults and analyzes citizen tolerance and expectations. The District's goal is to kill 95 percent of mosquito larvae or adults when it uses insecticides. This goal is based on guidelines established by the Environmental Protection Agency for all insecticides and principles of integrated pest management, which emphasize using just enough insecticide to kill the targeted insect without overusing the product. However, achieving 95 percent control using *Bti* and methoprene, which are more specific to mosquitoes, can be more difficult than when using broader-spectrum synthetic insecticides.

The District's control efforts begin with developing an inventory of potential larval breeding habitats including records of larval production. The District has identified and mapped over 65,000 potential and known larval breeding sites. District staff record the number and kind of larvae found along with treatment information for every site, which allow them to target larval control treatments to the most productive breeding sites. The District updates section maps to reflect changes in breeding sites. The District's 1994 self-assessment identified a goal of updating all maps every five years. In 1994, over 98 percent of the maps were less than five years old.[10] Staff have continued to update recently treated breeding site maps annually. Breeding site maps for rural areas not receiving larval insecticide treatments have not been routinely updated.[11]

8 Interagency Panel on MMCD Effectiveness, "Summary and Status," March 19, 1996.

9 Metropolitan Mosquito Control District, *Self-Assessment*: 13, 14, 19, 22.

10 Metropolitan Mosquito Control District, *Self-Assessment*: 13-14.

11 The District is changing to a new mapping system with a goal of entering all of the larval breeding sites in Priority Area 1 into the new system by March 1, 1999.

Material Efficacy

In its public relations materials, MMCD states that it applies insecticides to approximately 15,000 acres of the worst mosquito larval breeding areas in the District after each significant summer rain. The District claims that these treatments prevent a minimum of three billion mosquito larvae from emerging as adults and result in tolerable levels of adult mosquitoes in most parts of the metropolitan area.[12] MMCD used the results of larval insecticide efficacy testing to form the basis for this statement. The District monitors larval mosquito populations to measure the results of treatments in some breeding sites. We found that:

- **Most of the insecticides used by the District to kill mosquito larvae have not met the District's goal of killing 95 percent of the larvae.**

Only methoprene pellets used to kill cattail mosquito larvae consistently met the District's goal.

We examined the District's efficacy data for *Bti* granules and methoprene pellets and briquets used to kill floodwater and cattail mosquito larvae. Only methoprene pellets, when used to kill cattail mosquitoes, consistently met the District's goal of killing at least 95 percent of the larvae.

MMCD measures the effectiveness of methoprene briquets and pellets for killing cattail mosquito larvae using "emergence cages," netted structures covering approximately one square meter of area in a breeding site. MMCD places 6 emergence cages at each of 24 test sites: 8 sites treated with methoprene briquets, 8 treated with methoprene pellets, and 8 untreated or control sites. Staff vacuum adult mosquitoes from the cages twice a week from early June to early August. MMCD compares the average adult emergence counts from the two sets of treated sites with the average number from the untreated sites to determine the effectiveness of methoprene briquets and pellets at inhibiting emergence. We found that:

- **Methoprene briquets and pellets reduced the number of cattail mosquitoes emerging from treated sites by at least 92 percent in 1995 and 1996.**

In 1995 and 1996, the two years of data that we reviewed, MMCD determined that breeding sites treated with methoprene pellets had a 99 percent reduction in mosquito emergence compared with untreated sites.[13] Sites treated with methoprene briquets had 92 percent and 96 percent reductions in mosquito emergence for 1995 and 1996, respectively, compared with untreated sites.

MMCD measures the efficacy of *Bti* granules by comparing mosquito larvae counts from breeding sites before *Bti* treatments with counts taken 24 to 48 hours after treatment at randomly selected sites treated by helicopter. We found that:

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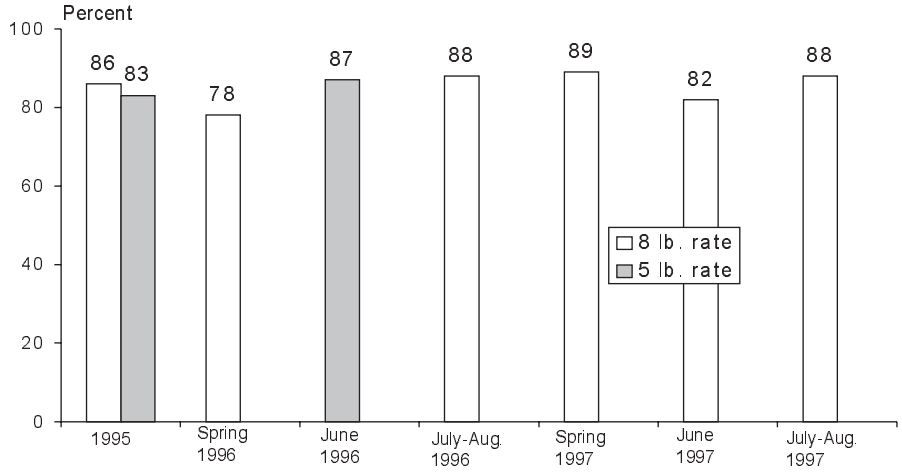
12 Metropolitan Mosquito Control District, "Fact Sheet: Program Effectiveness," July 18, 1996.

13 The District did not conduct material efficacy tests for cattail mosquitoes in 1997 or 1998 because the emergence cages were being used to test an experimental product.

- **The average control achieved with *Bti* granules, the insecticide that accounted for most of the larval breeding acres treated, ranged from 78 to 89 percent in recent years.**

We reviewed MMCD's *Bti* efficacy data for 1995 through 1997. Since we obtained similar figures as those reported by the District in most cases, we concluded that MMCD's calculations were correct.[14] Figure 4.1 summarizes the percent control achieved by the District with *Bti* granules during this time. During these years, applications of *Bti* granules accounted for between 85 and 90 percent of acres treated for larval control.

Figure 4.1: Average Percent Control of Mosquito Larvae with *Bti* Granules, 1995-97



NOTE: The Metropolitan Mosquito Control District applies *Bti* granules at two different rates: 5 pounds and 8 pounds per acre. Factors such as time of the year, water quality, temperature, and larval density will affect the effectiveness of *Bti* and the application rate the District uses.

SOURCE: Metropolitan Mosquito Control District.

Bti usually has killed between 78 and 89 percent of mosquito larvae.

In 1995, MMCD used *Bti* at 5 pounds and 8 pounds per acre rates and achieved control of 83 and 86 percent respectively. In 1996, MMCD applied *Bti* at different rates at different times during the year. MMCD used *Bti* at the 5 pound rate during the summer (June) that provided 87 percent control. In spring (through May) and late summer (July and August), MMCD applied *Bti* at the 8 pound rate and reported control of 78 and 88 percent, respectively. The District said it tested additional sites in the spring of 1996 because of low control rates obtained initially, and in the subsequent counts found control of 90 percent.[15]

14 In two instances we were unable to replicate MMCD's reported efficacy results for *Bti* using the District's data. Our calculation of the percent control achieved with *Bti* in the spring of 1996 was 73 percent compared with 78 percent reported by MMCD and our calculation for early summer (June) 1997 was 74 percent compared with 82 percent reported by MMCD.

15 Metropolitan Mosquito Control District, *1996 Operational Review and Plans for 1997*, March 1997: 36.

MMCD also measured the efficacy of *Bti* for three periods in 1997 at sites treated with the 8 pounds per acre rate. MMCD reported an overall control rate of 88 percent. A different brand of *Bti* granules, being tested by MMCD in 1997, provided control of 94 percent when applied by air at the 8 pound rate.

MMCD measures the effectiveness of methoprene briquets and pellets for killing floodwater mosquitoes by comparing the number of larvae in a sample that emerge as adults from treated and untreated sites. Using a specific formula, District staff have calculated an "emergence inhibition rate" for each treated site.[16] To get a district-wide average, MMCD has calculated the average of the site-specific "emergence inhibition rates." Using this method, the District has given each site an equal consideration or weight. If the District used average pre- and post-treatment counts to calculate the district-wide emergence inhibition rate, it would give greater weight to observations from sites with higher pre-treatment counts. Obviously, the two methods will give different results. When asked to comment on these two methods, a University of Minnesota entomologist responded that there may be no right way to evaluate control across sites. However,

- **We have other concerns about how the District has calculated and presented information on the effectiveness of methoprene products used to control floodwater mosquitoes.**

The District needs to review and document how it measures the effectiveness of methoprene products used to kill floodwater mosquitoes.

We noted the following concerns. First, we were not able to replicate MMCD's control figures for 1995 and 1996 using the District's data. According to District staff, a former staff person had completed the 1995 and 1996 "emergence inhibition rates." District staff were unable to give us information on how those calculations were made in 1995 and 1996. In 1997, MMCD changed the way it calculated the effectiveness of methoprene pellets used to kill floodwater mosquitoes by restricting analysis to sites that were treated using seeder applicators and for which samples were collected between 6 and 30 days after application.[17]

Second, in 1997 the District made some changes to its data that may not be appropriate. In 1997, when the "emergence inhibition rate" for a site was negative, the District changed the rate to a positive number. In *Bti* efficacy calculations, the District changes negative numbers to zero indicating no effect. Changing negative rates to positive ones indicates a positive effect when none was shown and increases the overall control rate calculated. District staff have noted that these were typographical errors. While the use of two positive values did not change the results in this instance, we have raised the issue because of our concerns about the methods and quality controls used to calculate material efficacy.

16 The formula, developed by Dr. Mir Mulla, is: Percent reduction (or emergence inhibition) = 100 - (C1/T1 x T2/C2) 100. Where C1 = average number of larvae in pre-treatment control (untreated) sites; T1 = average number of larvae in pre-treatment treated sites; C2 = average number of larvae in post-treatment control (untreated) sites; and T2 = average number of larvae in post-treatment treated sites.

17 The time restriction reflects the manner in which methoprene pellets work. According to MMCD, pellets begin to provide control six days following treatment. Since pellets are a 30-day control material, the sampling time frame was restricted to within 30 days of treatment.

Third, the information the District reported in its *1997 Operational Review and Plans for 1998* was not correct. District staff supplied us with corrected information as shown in Table 4.1, noting that the draft data were not changed before the report was released. Finally, in 1996 and 1997, the District's evaluation of control achieved with methoprene briquets was based on a sample of only five sites. The District acknowledged in its 1997 operational review that these efficacy tests were based on a small sample size. We recommend that:

- **The District should clarify how it measures the effectiveness of methoprene products used to kill floodwater mosquito larvae and institute data management procedures outlining the methods.**

The effectiveness of methoprene products used to kill floodwater mosquitoes has been inconsistent.

Table 4.1: Average Percent Control with Methoprene for Floodwater Mosquitoes Reported by the Metropolitan Mosquito Control District, 1995-97

Percent Control Reported	1995	1996	1997	1997 MMCD Corrected
Briquets	82% (*N*=106)	55% (*N*=5)	81% (*N*=5)	NA NA
Pellets	88% (*N*=63)	80% (*N*=66)	77% (*N*=69)	73% (*N*=39)

NOTE: NA = Additional data were not available.

SOURCES: Metropolitan Mosquito Control District, *1997 Operational Review and Plans for 1998*; Electronic-mail message from Mark Smith, Technician, October 26, 1998.

Annual fluctuations in the effectiveness of methoprene products to kill floodwater mosquitoes are evident in Table 4.1. For instance, average control achieved by methoprene briquets was 82 percent in 1995 and 55 percent in 1996. The District reported that the average control achieved was negatively affected by treating only the more difficult to reach breeding sites.[18] In addition, the average control achieved with methoprene pellets as reported by MMCD has declined from 88 percent in 1995 to 73 percent in 1997. Sometimes MMCD staff have attributed these changes to weather conditions, other times the reason for changes has not been known. We recommend that:

- **The Metropolitan Mosquito Control District should critically examine its use of methoprene briquets and pellets to control floodwater mosquito larvae considering both efficacy and cost factors.**

18 Metropolitan Mosquito Control District, *1996 Operational Review*: 35.

In its 1996 operational review, the District noted that it reduced the use of methoprene briquets because of high costs and "inconsistent effectiveness."[19] The review also stated that "Performance of methoprene products must improve if MMCD is to achieve the target rate of at least 95 percent control in treated mosquito breeding sites."[20] The District's 1997 operational review did not express any concerns about the effectiveness of methoprene products. In 1998, the District increased the number of sites sampled to test the effectiveness of methoprene pellets and it sampled sites treated with 90-day briquets (a product not used in prior years), however only five sites could be analyzed for 150-day briquets.[21] If the District continues to use methoprene briquets, we suggest that the number of sample sites used to calculate material efficacy be increased. According to its 1999 budget, the District plans to improve its measurement of effectiveness by further increasing the number of applications that are evaluated.

In addition to material efficacy testing, the District uses an outside laboratory to test the active ingredient content of methoprene products before they are accepted. MMCD has a supplier certification program that requires in-house testing of products before a vendor's bid will be considered. It also tests different product formulations and new products that might have higher control rates.

In the early 1990s, the District studied the insecticides used to kill adult mosquitoes.

The District sponsored a number of in-house studies in the early 1990s on the insecticides it used to kill adult mosquitoes. This research documented that the control achieved by permethrin, which is applied to foliage and kills mosquitoes when they land on the treated foliage, was significant for up to five days.[22] Other research focused on application methods for adult control materials and concluded that a combination of permethrin and resmethrin cold fogging treatments was most effective at reducing mosquito counts as measured with sweep net collections. This study also found that resmethrin alone showed no reduction in mosquito numbers at one day post-treatment.[23] Finally, a 1992 park study was designed to measure the effect of permethrin treatments (applied with a backpack mister) in four high-use parks. The study found that although there was no statistical significance in the number of adult mosquitoes between treated and untreated parks, fewer mosquitoes were measured in treated parks.[24] We also found that:

- **In 1996, the District conducted efficacy tests on the insecticides used to kill adult mosquitoes and estimated that the average adult mosquito reduction in treated sites was about 57 percent.**

19 *Ibid*., 21.

20 *Ibid*., 35.

21 We were unable to review the 1998 methoprene efficacy data because they were not available until late in the project.

22 Merry L. Holliday-Hanson, Chris E. Boxmeyer, Susan L. Palchick, "Residual Effects of Punt Applied as a Barrier Treatment Against *Aedes Vexans* in Wooded Areas in Minnesota," unpublished, Proceedings from 1992 California Mosquito Vector Control Association, 1992.

23 Metropolitan Mosquito Control District, "1992 Mosquito Adulticide Test," unpublished, 1993: 1, 4.

24 Chris Boxmeyer and Susan Palchick, "Comparison of Evening Adult Mosquito Numbers in Treated v. Untreated Parks Using Whole-Person Bag Samplers and CO_2 Traps," unpublished, undated.

In 1996, the District sponsored an evaluation of resmethrin and permethrin in 20 treated sites in Anoka, Dakota, Hennepin, and Washington counties. While some sites showed a reduction of over 90 percent, other sites showed zero reduction in the adult mosquito population.

In an effort to evaluate the effectiveness of insecticides used to kill adult mosquitoes, the District revised its adult mosquito treatment field form to provide for the collection of pre- and post-treatment adult population counts in 1998. Comparison of the pre- and post-treatment adult mosquito counts showed a 90 percent reduction in the number of adult mosquitoes following treatment. However, these data were not collected as part of a designed, supervised research study. One of our concerns with the 1998 pre- and post-treatment data is that the majority of counts used the "slap test" sampling method, a subjective method of obtaining adult mosquito counts.[25] The 1996 study used CO_2 traps to sample adult mosquito populations. According to the District, "this sampling method provides . . . a more standardized measure [of adult mosquito populations] than the widely used slap count."[26] Other concerns with using the 1998 pre- and post-treatment data as a measure of effectiveness include that apparently there were no written procedures on how to select a treatment to sample or the timing and location of the post-treatment collections and technical service staff did not supervise the collection process. We recommend that:

We have some concerns about using 1998 pre- and post-treatment adult mosquito counts to measure effectiveness.

- **The District should assign a high priority to measuring the effectiveness of adult insecticides in scientifically designed and supervised field studies in 1999 and use the results of these studies to evaluate the proper role for adult mosquito treatments in its mosquito control efforts.**

Based on past District-sponsored studies, the effectiveness of resmethrin and permethrin in killing adult mosquitoes does not compare favorably with the effectiveness achieved with some larval insecticides. While permethrin appears to kill mosquitoes for up to five days, the effectiveness of resmethrin at controlling mosquitoes following immediate exposure has been called into question by the District's own research. Finally, the District has not conducted any research on the effects of resmethrin and permethrin on other insects not targeted for control, such as bees.[27]

Citizen Tolerance and Expectations

Over the years, MMCD has conducted studies on citizen tolerance and expectations using public opinion surveys, focus groups, and field sampling of

25 Field staff do slap counts by standing in a location and counting the mosquitoes that land on them.

26 Metropolitan Mosquito Control District, *1996 Operation Review*: 37.

27 Some reviews on the nontarget impact of these adult insecticides have been conducted. As noted in Chapter 2, the World Health Organization reviewed scientific literature and concluded that resmethrin and permethrin were unlikely to attain levels of environmental significance when used under recommended conditions.

adult mosquito populations.[28] Generally, these studies have found that:

1. When three or more mosquitoes approach a person in five minutes, most people will use repellent or go indoors. When more than 11 mosquitoes attack a person in five minutes, most people will go indoors even if using a repellent.

2. People vary in their tolerances of three or more mosquitoes in five minutes, but all people were bothered when more than 11 mosquitoes attacked in five minutes.

Based on these data, the District identified the level at which mosquito populations interfere with people's enjoyment of the outdoors as two mosquitoes approaching a person within five minutes. These results were used to develop the District's threshold for treatment of adult mosquitoes—two mosquitoes in two minutes for sweep net collections or slap counts.

Adult Collection Data

Adult mosquito populations are the ultimate measure of MMCD mosquito control efforts. Entomologists we interviewed seem to agree that it is also the most difficult factor to measure because it involves relating larval control to regional adult populations and the number of mosquitoes in someone's backyard. An additional difficulty involves measuring citizen expectations and making judgments about something that did not happen. MMCD conducted several adult mosquito population studies in the early 1990s in an attempt to document effectiveness of its operations. We found that:

- **The results of District-sponsored studies on the overall effectiveness of mosquito control efforts generally have been inconclusive.**

In 1993, the District sponsored two studies that used data on adult mosquito populations to measure the overall effectiveness of its mosquito control efforts. One study compared data from light traps located inside and outside the District. Another study compared data on mosquito populations in the Twin Cities area from 1939, before the District existed, with data from 1963 and 1993. The results of both of these studies were inconclusive with some observations showing lower mosquito populations outside the District or before the District was created. These studies illustrate the difficulty of designing a field study where environmental factors (such as mosquito breeding habitat and weather) vary among multiple locations and over time.

The Interagency Panel on MMCD Effectiveness recommended that MMCD measure effectiveness in two areas: 1) breeding acres treated and efficacy of materials used, and 2) perceptions of effectiveness in citizens' backyards. In

28 Nancy R. Read, Jay R. Rooker, and Joseph P. Gathman, "Public Perception of Mosquito Annoyance Measured by a Survey and Simultaneous Mosquito Sampling," *Journal of the American Mosquito Control Association*, 10(1), 1994: 79-87; Nancy R. Read, "Public Perceptions and Tolerance of Mosquitoes and Biting Gnats and Willingness to Pay for Reduced Populations: Results of a Focus Group Study Conducted August 1995," unpublished, January 1996.

addition to sponsoring focus groups, the panel's work resulted in a 1995 computer simulation that used GIS data to analyze a rainfall event, breeding site treatments, and the resulting adult mosquito populations. MMCD staff have not continued to use this technique to study effectiveness because of limited staff resources.

While the District routinely collects adult mosquito population data using light traps and sweep net collections, it has not used these data to demonstrate its overall effectiveness because many other factors can influence the distribution and presence of mosquitoes. Instead, District staff have relied on weekly adult mosquito population data to identify breeding sites where larval control was needed and areas that may benefit from adult mosquito treatments. Table 4.2 illustrates how adult mosquitoes populations varied in the Twin Cities area in 1997.

Table 4.2: Light Trap Mosquito Collection Totals, 1997

	St. Paul	Lake Elmo	Lino Lakes	Elm Creek Park	Carlos Avery	Season Total	Average per Night	Percent Female
Selected Mosquito Species:								
Floodwater	242	5,811	10,315	10,252	23,153	49,773	72.66	54.85%
Tree hole	1	20	1	3	0	25	0.04	0.03
Cattail	5	49	795	833	31,517	33,199	48.47	36.58
All Species:								
Female Total	273	6,622	12,108	12,879	58,846	90,746	132.48	
Male Total	193	1,499	12,788	3,823	5,234	23,537	34.36	
Grand Total	466	8,121	24,896	16,702	64,080	114,283	166.84	

SOURCE: Metropolitan Mosquito Control District, *1997 Operational Review and Plans for 1998*: 27.

Compared with other states we contacted, MMCD uses similar techniques to monitor the effectiveness of its mosquito control program. Most of the states we contacted rely on pre- and post-treatment sampling, light trap collections, and citizen complaints to monitor the effectiveness of mosquito control activities.

INSECT-BORNE DISEASE PREVENTION

The District formally began LaCrosse encephalitis (LAC) prevention activities in 1987. Its goal is to effectively monitor and control disease carrying mosquitoes to protect human health.[29] Control efforts focus on the tree hole mosquito, a potential carrier for LAC. MMCD uses the number of LAC cases to demonstrate effectiveness. According to Minnesota Department of Health data:

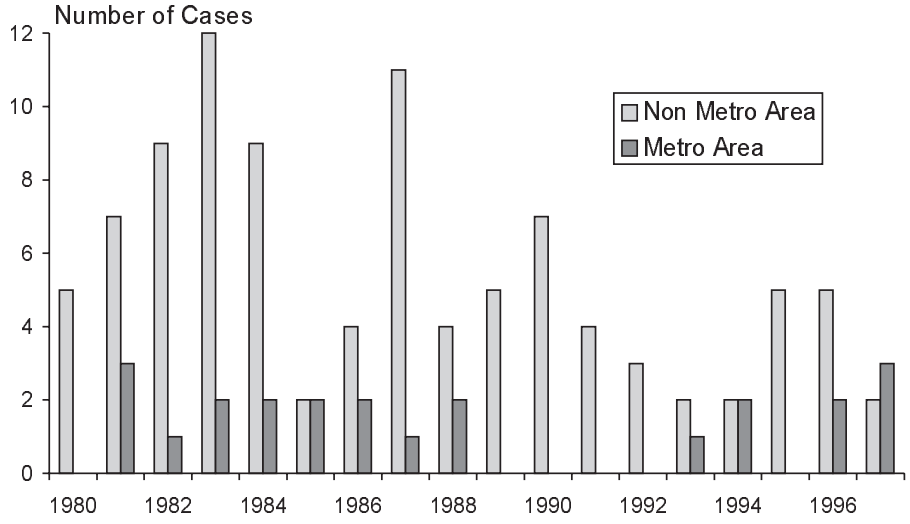
29 Metropolitan Mosquito Control District, *Self-Assessment*: 9.

- **The number of reported LaCrosse encephalitis cases in the Twin Cities metropolitan area has declined since 1987.**

- **The incidence of LaCrosse encephalitis has been lower in metropolitan counties since 1985 compared with counties in southeastern Minnesota.**

Figure 4.2 illustrates that there were fewer reported cases of LaCrosse encephalitis in the Twin Cities area after 1987 than before. Prior to 1987, the metropolitan area had averaged between two and three cases of LaCrosse encephalitis a year. No cases of LaCrosse encephalitis were reported in the Twin Cities area from 1989 through 1992 and in 1995, two were reported in both 1994 and 1996, and three were reported in 1997.[30] Table 4.3 shows that metropolitan area counties had much lower LaCrosse encephalitis incident rates than other Minnesota counties.

Figure 4.2: LaCrosse Encephalitis Cases, 1980-97



NOTE: Ramsey County was the county of residence for one case of LaCrosse encephalitis in 1993, but the exposure occurred in Wisconsin.

SOURCE: Minnesota Department of Health.

Public health and MMCD staff caution that while the occurrence of LAC could be a reasonable measure of effectiveness, it has limitations. The occurrence of LAC may involve factors that MMCD does not have any control over, such as the diagnosis and reporting of the disease. LAC is an under diagnosed disease, whose spectrum of illness can range from asymptomatic to life threatening. In regions where LaCrosse encephalitis occurs, there are probably more cases occurring than are reported.

30 Ramsey County was the county of residence for the one metropolitan case in 1993, but the exposure occurred in Wisconsin.

Table 4.3: LaCrosse Encephalitis Incidence Rates by County, 1985-96

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Metro Counties													
Anoka	--	--	--	--	--	--	--	--	--	--	--	--	1.1
Dakota	1.1	1.0	--	1.8	--	--	--	--	--	--	--	--	--
Hennepin	0.3	--	0.3	--	--	--	--	--	--	0.7	--	0.7	0.7
Ramsey	--	--	--	--	--	--	--	--	0.7	--	--	--	--
Washington	--	1.8	--	--	--	--	--	--	--	--	--	--	--
Non Metro Counties													
Blue Earth	4.0	--	--	--	--	--	--	--	--	--	--	--	--
Dodge	--	--	15.0	--	--	--	--	--	--	--	--	--	--
Fillmore	--	12.3	37.5	--	--	--	15.9	--	--	--	--	--	--
Goodhue	--	--	--	--	11.3	24.9	--	15.9	--	--	--	7.8	--
Houston	14.1	--	13.8	13.2	16.6	--	17.4	17.2	34.4	34.1	51.1	68.1	16.9
Olmsted	--	7.4	2.4	4.8	--	--	--	--	--	--	--	--	--
Wabasha	--	--	13.2	--	--	16.2	16.2	--	--	--	15.8	--	--
Winona	--	--	19.1	4.7	--	20.4	6.8	--	--	--	6.6	--	--
Wright	--	--	--	--	--	--	--	--	--	--	--	--	3.6

NOTE: Incidence rate = number of cases per 100,000 person-years of risk in children less than 20 years old.

SOURCE: Minnesota Department of Public Health.

BLACK FLY CONTROL

MMCD performs black fly material efficacy tests at treatment sites on large rivers as a condition of its Department of Natural Resources permit. MMCD also measures the effectiveness of its black fly program by reporting the reduction of average adult black fly counts over the years. The District does not do material efficacy tests after treatments on small streams.

Material Efficacy

The District strives to achieve 80 percent control of black fly larvae.

While MMCD does not have a written target efficacy rate for the black fly program, program staff indicated that they hope to achieve at least 80 percent control. The data provided by MMCD to the DNR in its permit applications (see Table 4.4) show that:

- **From 1995 to 1997, the average mortality achieved on each river was at least 80 percent, except for the Crow River in 1997.**

MMCD attributed the poor performance on the Crow River to one treatment with a very low efficacy rate (22 percent) that may have been due to the low discharge

Table 4.4: Average Mortality of Black Fly Treatments by River, 1995-97

River	1995	1996	1997
Crow	100% (*N*=4)	99% (*N*=3)	69% (N=3)
Minnesota	87 (*N*=15)	94 (N=10)	96 (*N*=23)
Mississippi	87 (*N*=12)	94 (*N*=9)	97 (*N*=6)
Rum	98 (*N*=10)	80 (*N*=13)	81 (*N*=17)

SOURCE: Metropolitan Mosquito Control District.

Average mortality of black fly treatments for 1995-97 was 80 percent or higher.

in the Crow at the time of application.[31] Table 4.4 also shows that over half of the average mortality figures by river for 1995-97 exceeded 90 percent. We also noted that:

- **In 1997, the percentage of treatments achieving a mortality rate of 80 percent or more varied by river— 53 percent of the tested treatments achieved that rate on the Rum and 67 percent on the Crow rivers, compared with 96 percent on the Minnesota and 100 percent on the Mississippi rivers.**

Table 4.5 shows that overall, over 90 percent of the samples from all large rivers achieved an efficacy rate of at least 80 percent in 1995, but that figure dropped to 80 percent in 1997. Much of this decline was explained by the performance of *Bti* liquid in the Rum River. A possible explanation suggested by MMCD was that there may have been a large black fly population upstream (outside the District) from the northern most treatment site on the Rum River.

Adult Collection Data

MMCD uses adult black fly counts from 1984 to present to show that its program has had an effect on the black fly population in the metropolitan area. As Table 4.6 shows, the counts revealed a drop in the annual average number of black flies captured from 17.95 in 1984 to 2.91 in 1997.

31 The number of treatments sampled varies by river and by year. For instance in 1997, all treatments on the Crow River were sampled, while about half of the treatments on the Mississippi River were sampled. MMCD's permit from DNR requires efficacy sampling for all river treatments, but DNR staff are not concerned that not all treatments are sampled. DNR staff monitoring the black fly program told us that they rely more on site-specific efficacy data than average efficacy by river when reviewing the program's performance.

Table 4.5: Percentage of Black Fly Treatments with Efficacy of 80 Percent or More, 1995-97

River	1995	1996	1997
Crow	100% (*N*=4)	100% (*N*=3)	67% (*N*=3)
Minnesota	87 (*N*=15)	100 (*N*=10)	96 (*N*=23)
Mississippi	92 (*N*=12)	89 (*N*=9)	100 (*N*=6)
Rum	100 (*N*=10)	69 (*N*=13)	53 (*N*=17)
Overall	93 (N=41)	86 (*N*=35)	80 (*N*=49)

SOURCE: Metropolitan Mosquito Control District.

MMCD and DNR staff have expressed some concerns with the method used to monitor one species of black fly, *S. venustum*, primarily because of the time of day the monitoring is done.[32] DNR's concerns extend to the monitoring method more broadly, in part because the method was developed for sampling mosquitoes, not black flies. The MMCD consultant working with the black fly program believes that the large drop in the adult black fly counts that has been observed since the start of the program clearly shows that the program is having an effect on the black fly population. The DNR staff person assigned to monitor the black fly program is convinced MMCD is killing black flies because of the efficacy rates the District achieves, but he does not rely on adult black fly counts to judge effectiveness of the black fly program.

SUMMARY

Adult mosquito populations are the ultimate measure of MMCD's mosquito control efforts. However, it is also the most difficult factor to measure because it involves relating mosquito larval control to regional adult populations, while accounting for variables such as number of mosquitoes produced from breeding sites, weather, flight distance of adult mosquitoes, and citizen expectations. District-sponsored studies on the overall effectiveness of adult mosquito control

32 Black fly samples are typically taken in the morning, probably before *S. venustum* become very active. MMCD is doing research to better understand the time of day when *S. venustum* are active with the goal of developing a sampling method that will effectively monitor the population without having to use human collectors.

Table 4.6: Annual Average Number of Adult Black Flies Collected, 1984-97

Year	All Species[a]
1984	17.95
1985	14.56
1986	11.88
1987	6.53
1988	1.60
1989	6.16
1990	6.02
1991	2.59
1992	2.63
1993	3.00
1994	2.41
1995	1.77
1996	0.64
1997	2.91

[a]All species includes *S. luggeri, S. meridionale, S. johannseni, S. vittatum,* and *S. venustum.*

SOURCE: Metropolitan Mosquito Control District, *1997 Black Fly Program Report* submitted to Minnesota Department of Natural Resources, February 1998: 18.

The District uses the number of adult black flies collected to show that control efforts are having an effect.

have been inconclusive. Instead, the District has used the effectiveness of larval insecticides it applies as a measure of effectiveness.

The District's goals is to kill 95 percent of mosquito larvae or adults when it uses insecticides. We examined the District's material efficacy data for 1995 through 1997 and found that most of the insecticides used by the District to kill mosquito larvae did not met the 95 percent goal. Methoprene briquets and pellets used to kill cattail mosquito larvae have performed the best (92 to 99 percent control). *Bti* granules, which account for about 90 percent of breeding site acres treated, averaged 78 to 89 percent control in 1995-97. We were not able to replicate MMCD's control figures for methoprene products used to kill floodwater mosquitoes. We recommend that the District reevaluate its use of methoprene briquets and pellets to control floodwater mosquito larvae, looking at both efficacy and cost factors.

The District tested the effectiveness of resmethrin and permethrin used to kill adult mosquitoes in 1996, when it estimated that an average of 57 percent of adult mosquitoes were killed in treated sites. Based on the results of District-sponsored studies in the early 1990s, the effectiveness of these adult insecticides appears to be questionable. In 1998, the District collected pre- and post-treatment adult mosquito counts. However, we have some concerns about using these data to evaluate the effectiveness of adult insecticides. We recommend that the District evaluate the effectiveness of resmethrin and permethrin in scientifically designed and supervised field studies in 1999 and reexamine the role of adult mosquito treatments based on the results of its analysis.