Metropolitan Mosquito Control District

2016 Operational Review & Plans for 2017

Annual Report to the Technical Advisory Board

Staff from the East region picked up over 100 tires as part the Great Mississippi Riverboat Cleanup, 2012.

Metro Counties Government Center ~ 2099 University Avenue West ~ St. Paul, MN 55104-3431
www.mmcd.org

Metropolitan Mosquito Control District

Mission

The Metropolitan Mosquito Control District's 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.

Governance

The Metropolitan Mosquito Control District, established in 1958, controls mosquitoes and gnats and monitors ticks in the metropolitan counties of Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington. The District operates under the eighteen-member Metropolitan Mosquito Control Commission (MMCC), composed of county commissioners from the participating counties. An executive director is responsible for the operation of the program and reports to the MMCC.

Metropolitan Mosquito Control Commission 2017

Julie Braastad	Anoka County
Rhonda Sivarajah	Anoka County
Robyn West	Anoka County
James Ische	Carver County
Tom Workman	Carver County
Thomas Egan	Dakota County
Mike Slavik	Dakota County
Liz Workman	Dakota County
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Deb Goettel	Hennepin County
Jeff Johnson	Hennepin County
Blake Huffman	Ramsey County
Mary Jo McGuire	Ramsey County
Janice Rettman	Ramsey County
Michael Beard	Scott County
Tom Wolf	Scott County
Gary Kriesel	Washington Co.
Fran Miron	Washington Co.

Technical Advisory Board

The MMCC formed the TAB in 1981 to provide annual, independent review of the field control programs, to enhance inter-agency cooperation, and to facilitate compliance with Minnesota State Statute 473.716.

Technical Advisory Board Members 2016-2017

David Neitzel, Chair	Mn Department of Health
Donald Baumgartner	US EPA
Phil Monson	Mn Pollution Control Agency
Roger Moon	University of Minnesota
Gary Montz	Mn Dept. of Natural Resources
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Robert Sherman	Independent Statistician
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Metropolitan Mosquito Control District Contributing Staff

Stephen Manweiler	Executive Director
Sandy Brogren	Entomologist
Diann Crane	Assistant Entomologist
Janet Jarnefeld	Technical Services/Tick
Kirk Johnson	Vector Ecologist
Carey LaMere	Technical Services
Mike McLean	Public Affairs
Molly Nee	Administrative Assistant
Nancy Read	Technical Services Coordinator
Mark Smith	Tech. Serv./Control Materials
John Walz	Technical Services/Black Fly

MDH
Minnesota
Department
of Health

PROTECTING, MAINTAINING & IMPROVING THE HEALTH OF ALL MINNESOTANS

April 10, 2017

Commissioner Tom Wolf, Chair
Metropolitan Mosquito Control Commission
2099 University Avenue West
St. Paul, MN 55104

Dear Commissioner Wolf:

The Technical Advisory Board (TAB) met on February 21, 2017 to review and discuss MMCD operations in 2016 and plans for 2017. Since the Board's formation in 1981, the member representatives have met at least once per year to provide independent review of field control programs and to enhance inter-agency cooperation.

After an excellent interchange of questions and information between the TAB and MMCD staff, the TAB approved the following resolution.

1. The TAB commends MMCD for its efforts to improve the cost efficiency of its programs while continuing to protect public health through vector control, and considering long-term environmental effects of its programs.

Sincerely,

David F. Neitzel

David Neitzel, MS
Chair, Technical Advisory Board
Minnesota Department of Health

DFN:dd

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APPENDICES

Executive Summary

The Metropolitan Mosquito Control District (MMCD or the District) strives to provide cost-effective service in an environmentally sound manner. This report presents MMCD staff efforts to accomplish that goal during 2016 through mosquito, black fly and tick surveillance, disease monitoring, mosquito and black fly control, new product testing, data management, and public information. It also presents plans for 2017 as we continue to provide an integrated mosquito management program for the benefit of metro area citizens.

Surveillance

The National Weather Service declared 2016 was the wettest year on record for the Twin Cities! Average rainfall in the District from the weeks of May 2 through September 26, 2016 was 27.76 inches, which is 8.12 inches above the 56-year District average of 19.54 inches. There were 18 rain events sufficient to produce seven major and 11 small to medium sized summer *Aedes* broods and the majority of the rain occurred in July, August, and September. Adult summer *Aedes* populations were below average for most of the summer, but the sweep nets and CO_2 traps detected an unusually high late season peak of summer *Aedes* levels on August 29, following the major District-wide rain event of August 11. Vector species *Cx. tarsalis* collections in CO_2 traps were consistently low, while above-average temperatures for June, July and August favored *Cx. pipiens* population growth. Aspirator sample collections of vector *Ae. triseriatus* remained below the multi-year average most of the year despite the wet weather.

The District continued monitoring the distribution of ticks in the metro area. The average number of *I. scapularis* collected per mammal was 1.68 in 2016; this is a new record high and surpasses the previous high of 1.45 which had just been set in 2015. Another record number of *I. scapularis* positive sites (82) occurred in 2016, just surpassing the site total of 80 recorded in 2015.

Disease

District staff provides a variety of disease surveillance and control services, as well as public education, to reduce the risk of mosquito-borne illnesses such as La Crosse encephalitis (LAC), western equine encephalitis (WEE), eastern equine encephalitis (EEE), West Nile (WNV) encephalitis, as well as tick-borne illnesses such as Lyme disease and human granulocytic anaplasmosis (HGA). In 2016, the Minnesota Department of Health reported 14 cases of WNV in District residents. MMCD tested 795 mosquito pools using the RAMP® method, 51 of which were positive for WNV. Hot weather during the week of July 18 stimulated a rise in the WNV infection rate in mosquitoes which peaked for the season two weeks later at 7.6/1,000 *Culex* tested .There was 1 case of LAC diagnosed in a District resident. Eliminating water-holding containers that provide larval habitat for many vector species is an effective strategy for preventing mosquito-borne illnesses, and in 2016 staff removed over 20,000 such habitats, including recycling 18,417 tires collected from the field.

Control

MMCD's program focuses on control of mosquitoes while they are in the larval stage, and uses the insect growth regulator methoprene, the bacteria *Bacillus thuringiensis* var. *israelensis* (*Bti*) and *B. sphaericus*, and the bacterial product spinosad. Larvicide treatments in 2016 (305,972 acres) were lower than the record set in 2015 (348,883 acres). A cumulative total of 241,254 catch basin treatments were made in three rounds to control vectors of WNV. Adulticides were applied to 82,583 acres in response to widespread *Ae. vexans* emergence, customer calls, and increasing numbers of *Culex* (WNV vectors).

To control black flies in the metro area, MMCD treated 20 small stream sites with *Bti* when the *Simulium venustum* larval population met the treatment threshold. MMCD also made 58 large river treatments with *Bti* when the larval population of the target species met the treatment threshold.

Product and Equipment Testing

Quality assurance processes focused on product evaluations, equipment, and waste reduction. Before being used operationally, all products must complete a certification process that consists of tests to demonstrate how to use the product to effectively control mosquitoes. The District continued certification testing of the methoprene formulation MetaLarv™ S-PT on spring *Aedes* and the spinosad formulation Natular G on cattail mosquitoes. A natural pyrethroid formulation that meets USDA Organic standards (Merus®) was tested as an alternative ULV material. Tests of efficacy of the synthetic pyrethroid esfenvalerate (Onslaught®) as barrier control for vector species were also continued. These additional control materials can provide MMCD with more operational tools.

Data Management and Public Information

This year marked a milestone for MMCD data systems: all field data entry is now done through our web-based system, "Webster." Field staff no longer need PDAs and we are moving more and more functionality onto smart phones, making information easily accessible to inspectors. Webster is also available to all staff through PCs or any device with a web browser.

MMCD has also continued its efforts to contact beekeepers to get bee hive locations and ensure that mosquito control activity has minimal effect on bees.

Citizen requests for adult mosquito treatment increased substantially in 2016 compared to 2015, and calls requesting larval site checks doubled. Call volume reached its peak two weeks prior to Labor Day weekend, reflecting a late-season surge in the human-biting mosquito population District-wide. Although mosquito-borne Zika virus transmission does not occur in Minnesota, the specter of Zika virus and its effects was a frequent topic in national and local news, keeping mosquito issues prominent in the public's attention.

In 2016, MMCD continued to refine its sustainability strategy. We established specific quantifiable sustainability goals in each of these areas: 1) reducing energy usage; 2) reducing waste; 3) identifying and using renewable resources; and 4) social responsibility/health and wellness. The 2016 Sustainability Report is available through our website, http://www.mmcd.org/wp-content/uploads/2017/01/2016-Sustainability-Report.pdf.

Chapter 1 Mosquito Surveillance

2016 Highlights

- Rainstorms produced seven major mosquito broods
- Warm, dry, late spring; very wet July – September; wettest year in history!
- Major mosquito peak occurred in late August
- Identified nearly 25,515 larval samples
- Collected three *Culex erraticus* adults, one each in three trap locations
- *Aedes albopictus* larvae found at tire recycling facility in Savage

2017 Plans

- Evaluate placement of CO_2, gravid, and New Jersey traps
- Continue to monitor and study *Ae. japonicus*
- Maintain surveillance for *Ae. albopictus* and remain aware of other potential invasive species
- Continue to refine *Cs. melanura* surveillance

Background

The Metropolitan Mosquito Control District (MMCD or the District) conducts larval and adult mosquito surveillance to determine levels of mosquitoes present, measure annoyance, and to detect the presence of disease vector species. A variety of surveillance strategies are used because different mosquito species have different habits and habitat preferences. The District strives to obtain a complete picture of the mosquito population by weekly monitoring of host-seeking, resting, egg laying, and larval mosquitoes. By knowing which species are present in an area, and at what levels, the District can effectively direct its control measures.

Fifty-one known mosquito species occur in Minnesota, all with a variety of host preferences. Forty-five species occur in the District, 24 of which are human-biting. Other species prefer to feed on birds, large mammals, reptiles, or amphibians. Mosquitoes differ in their peak activity periods and in how strongly they are attracted to humans or trap baits (e.g., light or CO_2), therefore, we use a variety of adult mosquito collection methods to capture targeted species.

The District focuses on four major groups of human-biting mosquito species: spring *Aedes*, summer *Aedes*, *Coquillettidia perturbans,* and disease vectors. Snowmelt induces spring *Aedes* (15 species) eggs to hatch in March and April and adults emerge in late April to early May. These species have one generation each season; however, adults can live for three months and lay multiple egg batches. Summer *Aedes* (five species) begin hatching in early May in response to rainfall and warmer temperatures. Adults can lay multiple egg batches throughout the summer and can live up to two weeks. *Coquillettidia perturbans* (cattail mosquito) develops in cattail marshes. There is one emergence, which begins in early July. Disease vectors include *Aedes triseriatus*, *Culiseta melanura*, and *Culex* mosquitoes (*Cx. pipiens*, *Cx. restuans*, *Cx. salinarius*, and *Cx. tarsalis*). Adults are evident in early summer and they can produce multiple generations per year. Appendix A contains a species list and detailed descriptions of the mosquitoes occurring in the District.

2016 Surveillance

Rainfall

Rainfall is a key factor for understanding floodwater mosquito populations and planning control efforts. For over 50 years MMCD has used a network of rain gauges, read daily by staff or volunteers, to measure rainfall. These data were shared with the Minnesota State Climatologist's office for analysis, typically at the end of each month. Starting in 2011, we began entering our rain gauge data directly into the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) system to make the measurements available more quickly for each other, the National Weather Service (NWS), and the public. This system has limitations because of the sparse gauge network in some areas of the District.

The NWS River Forecast Centers (RFC) create a 4x4 km grid of precipitation estimates based on a combination of Nexrad radar, satellite, and ground rain gauge measures (including MMCD's gauges submitted through CoCoRaHS). Although it is not perfect, this dataset is one of the best sources of timely, high resolution precipitation information available.

The NWS declared 2016 was the wettest year on record for the Twin Cities area in Minnesota with 40.32 inches of precipitation, eclipsing the previous record of 40.15 inches back in 1911. Data goes back to 1871. Since 1959, average seasonal rainfall in the District is calculated from May through September. The rainfall for the weeks of May 2 through September 26, 2016 was 27.76 inches, which is 8.12 inches above the 57-year District average of 19.54 inches. Historical rain data from District and CoCoRaHS gauges were used to calculate the averages. The majority of the rain occurred in the second half of the season: July, August, and September (Fig. 1.1). April rainfall amounts are included in the graph to indicate their possible influences on adult mosquito emergence in May.

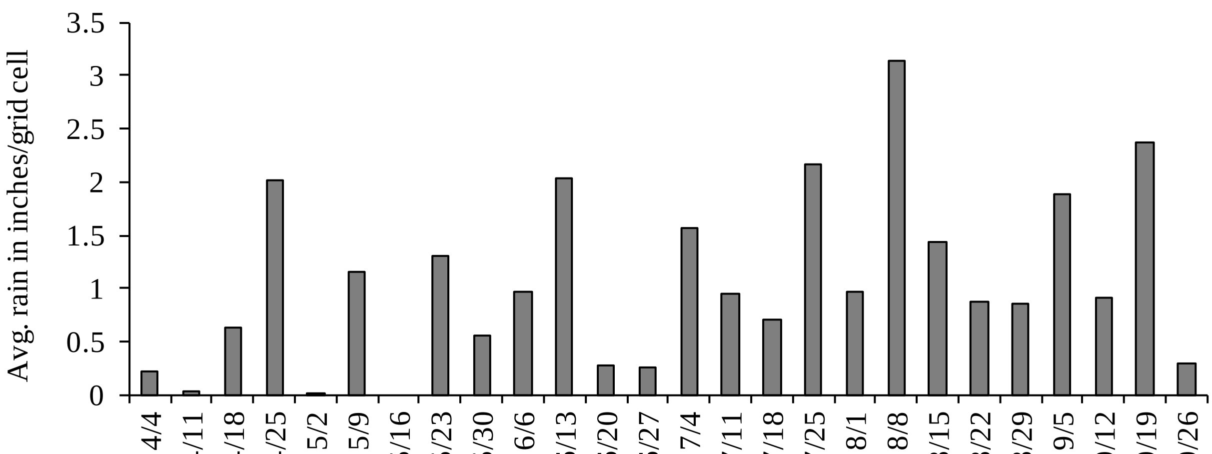


Figure 1.1 Weekly rainfall amounts per grid cell, 2016 (RFC data, Sunday – Saturday). Dates represent the Monday of each week.

Typically, spring *Aedes* mosquito larvae develop over a period of months (mid-March to early May), and summer species develop over a period of days (7-10). Water temperature and precipitation amounts influence how quickly larvae develop in sites. The winter of 2015-2016 was warm, with very little snow, thus, less snowmelt to induce hatching of larval spring *Aedes* mosquitoes. March was very warm, 8.5 °F above normal, and rainfall was slightly above normal (Fig. 1.2). The first larval sample of the year was taken on March 11. Warm weather in February and March resulted in the Freshwater Society declaring ice-out on Lake Minnetonka on March 17, the second earliest on record. This is 19 days earlier than 2015 and 28 days earlier than the April 14 median date.

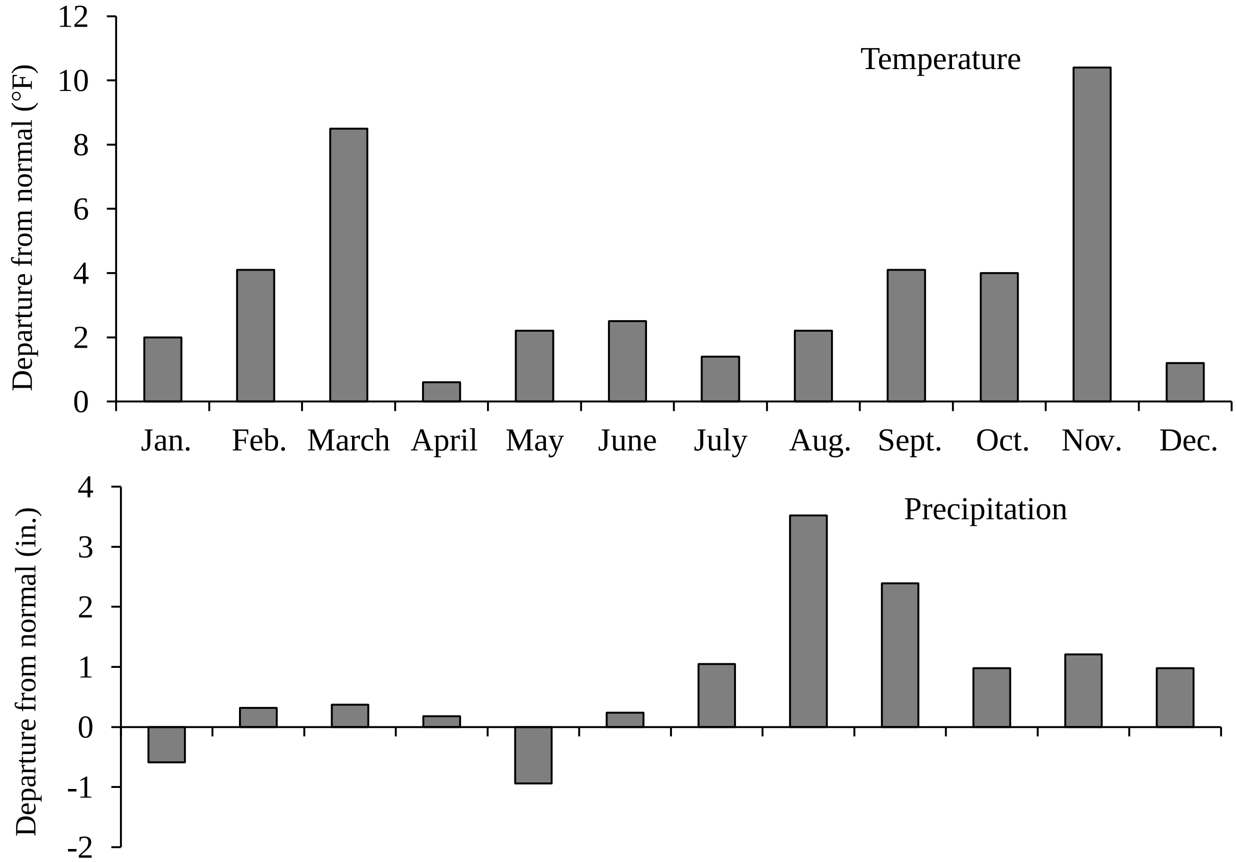


Figure 1.2 Monthly departures from normal for temperature and precipitation January-December, 2016 (source: National Weather Service, Twin Cities Station).

Figure 1.3 depicts the geographic distribution and magnitude of weekly rainfall received in the District from April through September 2016. Since some weeks had multiple rain events and broods, the cumulative weekly rainfall does not identify individual rain events. April had close to average temperatures and precipitation, but had a 2-inch rain event the week of April 25 that fueled the spring *Aedes* brood. There were 18 rainfall events sufficient to produce summer *Aedes* broods. Seven large broods and 11 small to medium sized broods occurred from May - September; the amount of area affected by rainfall, the amount of rainfall received, and the resultant amount of mosquito production determines brood size. On May 8, we switched from our spring *Aedes* control threshold to our summer *Aedes* threshold. May temperatures were above normal and below average for rainfall. Our first large brood did not occur until the week of June 13. Five of the large broods occurred late in July through the beginning of September.

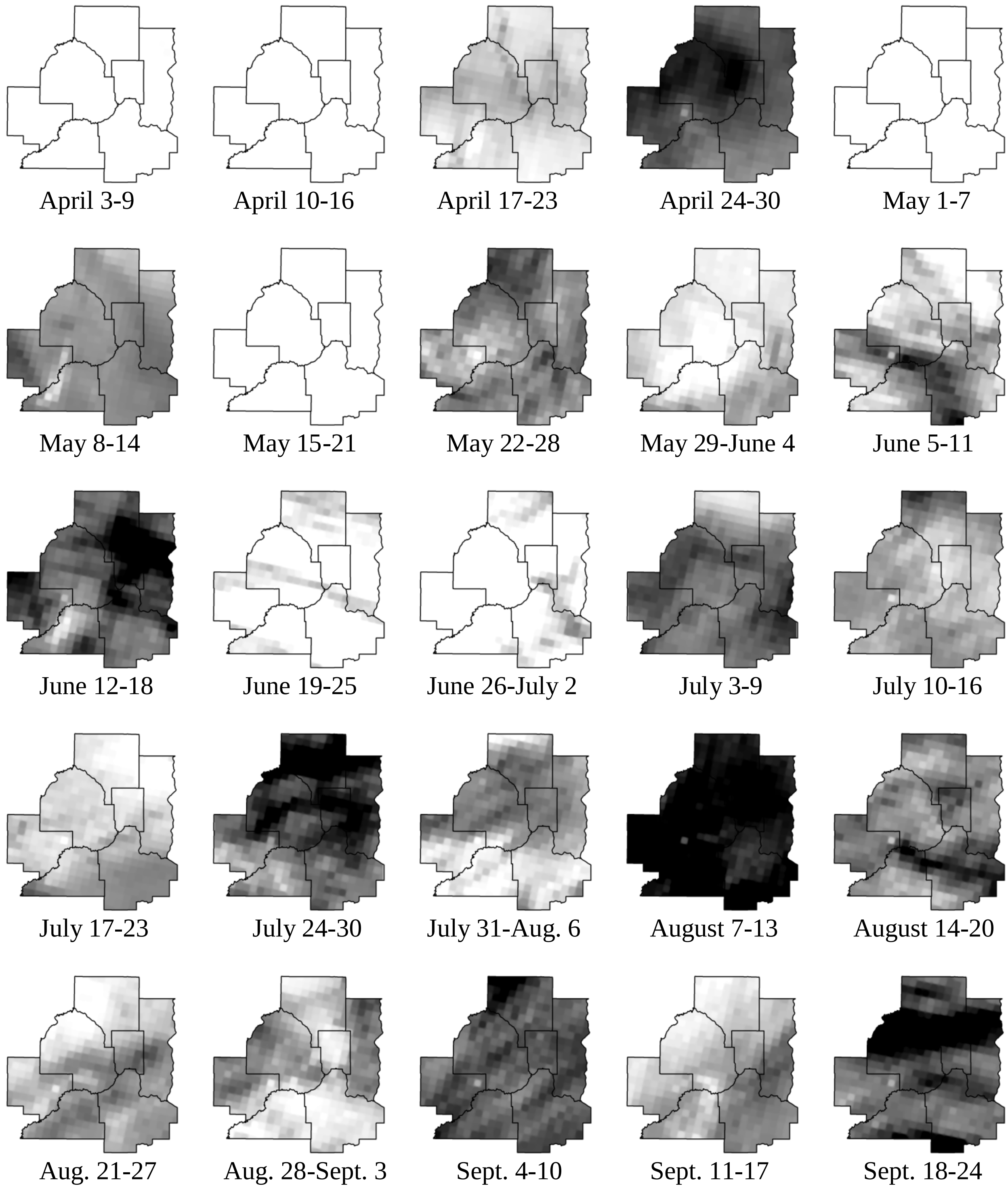
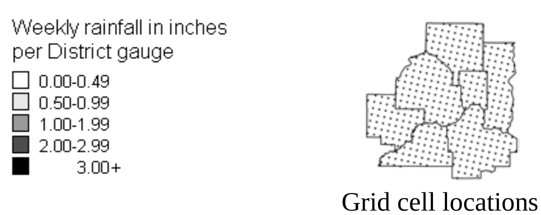


Figure 1.3 Weekly rainfall in inches, 2016. RFC corrected data using 407 4x4 km grid cells. Inverse distance weighting was the algorithm used for shading of maps.



Larval Collections

Larval mosquito inspections are done to determine if targeted species are present at threshold levels or to obtain species history in development sites. A variety of habitats is inspected to monitor the diverse fauna. Habitats include wetlands for *Aedes* and *Culex*, catch basins and stormwater structures for *Cx. pipiens* and *Cx. restuans*, cattail marshes for *Cq. perturbans*, tamarack bogs for *Cs. melanura*, and containers, tires, and tree holes for *Ae. triseriatus, Ae. albopictus,* and *Ae. japonicus*. The majority of larval collections are taken from floodwater sites using a standard four-inch dipper. The average number of larvae collected in a minimum of 10 dips is recorded as the number of larvae per dip. Larvae are placed in sample vials, and sent to the Entomology Lab for species identification.

To accelerate the identification of samples from sites to be treated by helicopter, larvae are identified to genus only, except for *Culex* larvae, which are identified to species to differentiate vectors. Staff process lower priority samples as time permits and those are identified to species. In 2016, lab staff identified 25,515 larval samples, the fifth highest amount in the last 26 years (Figure 1.4).

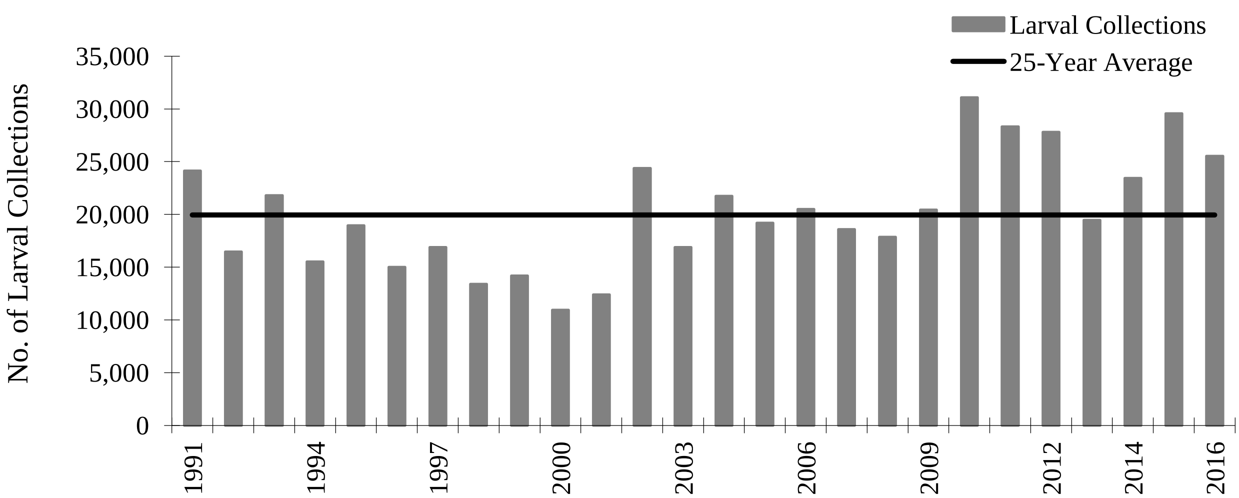


Figure 1.4 Yearly total larval collections, 1991-2016, and 25-year average.

The results of 10,273 samples identified to species, calculated as the percent of samples in which the species was present, is shown in Table 1.1. Most larval sampling takes place in natural wetlands but a significant amount of sampling is done in catch basins, stormwater structures, and other man-made features (e.g., swimming pools, culverts, artificial ponds). Those results are displayed separately (shaded column) from the natural wetlands results in Table 1.1. *Culex* mosquitoes are by far the most common species found in man-made features.

Aedes vexans is the most common species collected from natural development areas, occurring in 44.8% of the samples. The next three in the top five are non human-biting species: *Culex territans* (18.6%), *Culiseta inornata* (14.2%), and *Cx. restuans* (10.6%), a West Nile virus (WNV) vector. *Aedes cinereus* (8.9%), a spring and summer species was number five.

Table 1.1 Percent of samples where larval species occurred in wetland collections by facility and District total, and the District total for structure samples, 2016; the total number of samples processed to species is in parentheses

	Percent of samples where species occurred by facility							
Species	North (1,214)	East (2,432)	South Rosemount (2,750)	South Jordan (954)	West Plymouth (915)	West Maple Grove (667)	Wetland Total (8,932)	Structures Total (1,341)
Aedes abserratus	0.3	0.5	<	0.1	0.2	0.6	0.3	
aurifer		0.2					<	
canadensis	0.2	0.2	1.4	0.5	0.4		0.6	<
cinereus	11.8	14.8	4.0	4.3	9.5	8.5	8.9	0.2
communis			<				<	
dorsalis				0.2			<	
excrucians	8.2	5.4	1.8	0.6	4.6	10.3	4.5	
fitchii	2.7	1.4	0.6	0.4	0.4	2.1	1.2	
flavescens								
hendersoni								0.2
implicatus	1.5	0.2	<	0.2	0.5	1.0	0.4	
intrudens								
japonicus	0.3	0.2	0.4	0.3		0.3	0.3	13.0
nigromaculis								
punctor	<	0.7	0.1		0.2	0.1	0.3	
riparius	0.7	0.5	<	0.1	1.0	0.7	0.4	
spencerii								
sticticus	0.7		0.4	0.6		0.4	0.3	
stimulans	11.2	4.6	3.3	6.1	7.6	9.7	6.0	
provocans	1.5	0.2		0.1	0.3	0.3	0.3	
triseriatus		<			0.1		<	4.7
trivittatus	4.1	3.3	9.8	9.1	3.8	3.3	6.1	0.1
vexans	53.0	31.5	52.6	51.6	43.3	38.2	44.8	8.7
Ae. species	35.0	26.2	27.3	19.8	23.8	31.3	27.2	5.6
Anopheles earlei								
punctipennis	1.2	0.8	0.7	0.3	0.4		0.7	0.4
quadrimaculatus	0.2	0.6	<	0.5	1.1	0.1	0.4	<
walkeri			<				<	
An. species	1.8	3.6	1.4	1.4	2.6	1.3	2.2	1.0
Culex erraticus								
pipiens	3.6	1.1	2.7	4.2	6.3	3.9	3.0	37.5
restuans	9.6	7.9	12.0	11.3	17.0	6.7	10.6	76.2
salinarius	<	0.1			0.3		<	<
tarsalis	1.5	0.9	1.5	2.6	3.0	1.3	1.6	2.0
territans	12.2	34.4	11.2	18.3	14.2	9.4	18.6	8.8
Cx. species	3.3	2.3	2.5	3.7	7.3	2.1	3.2	43.9
Culiseta inornata	6.3	11.0	15.5	16.1	20.1	23.8	14.2	3.4
melanura								
minnesotae	0.2	1.2	0.1	0.1	1.2	0.5	0.6	
morsitans	<		<				<	
Cs. species	1.2	3.7	0.4	0.6	1.6	1.6	1.6	<
Or. signifera								0.1
Psorophora ciliata								
columbiae								
ferox	1.0	0.7	0.7	0.5			0.6	
horrida					0.1		<	
Ps. species	<	0.6	1.1	0.6			0.6	
Ur. sapphirina	0.9	3.5	0.3	1.0	0.5	1.0	1.4	<

< = percent of total is less than 0.1%

Adult Mosquito Collections

As stated earlier, the District employs a variety of surveillance strategies to target different behaviors of adult mosquitoes. Sweep nets are used to survey the mosquitoes attracted to a human host. We use carbon dioxide-baited (CO_2) traps with small lights to monitor host-seeking, phototactic species. New Jersey (NJ) light traps monitor only phototactic mosquitoes. Large hand-held aspirators are used to capture mosquitoes resting in the understory of wooded areas in the daytime. Gravid traps with liquid bait are used to attract and capture egg-laying *Culex* and *Aedes* species and ovitraps are used to collect eggs of container-inhabiting vector species (i.e., *Ae. triseriatus, Ae. japonicus, Ae. albopictus*). The information obtained from sampling is used to direct control activities and to monitor vector populations and disease activity—specimens collected are tested for disease. Treatment thresholds are discussed in Chapter 3: Mosquito Control.

Monday Night Network The sweep net and CO_2 trap data reported here are weekly collections referred to as the Monday night network. Employees took two-minute sweep net collections and/or set overnight CO_2 traps in their yards every Monday night from May - September. To achieve a District-wide distribution of CO_2 traps, other locations such as parks or wood lots are chosen for surveillance as well. Figure 1.5 shows the sweep net and CO_2 trap locations and their uses [i.e., general monitoring, virus testing, eastern equine encephalitis (EEE) vector monitoring]. CO_2 traps were operated once weekly for 20 weeks, May 9-September 19. Sweep net collections started on May 24, two weeks later than the CO_2 traps and ended on September 19.

Most of the mosquitoes collected are identified to species, but in some cases, species are grouped together to expedite sample processing. *Aedes* mosquitoes are grouped by their seasonal occurrence (spring, summer). Others are grouped because species-level separation is very difficult (e.g., *Ae. absERRATUS/punctor*, *Cx. pipiens/restuans*). Generally, the most abundant species captured in sweep nets and CO_2 traps are the summer *Aedes*, *Cq. perturbans*, and spring *Aedes*. *Culex tarsalis*, unlike the other *Culex* species that prefer birds as hosts, is also attracted to mammals, and is important in the transmission of WNV to humans.

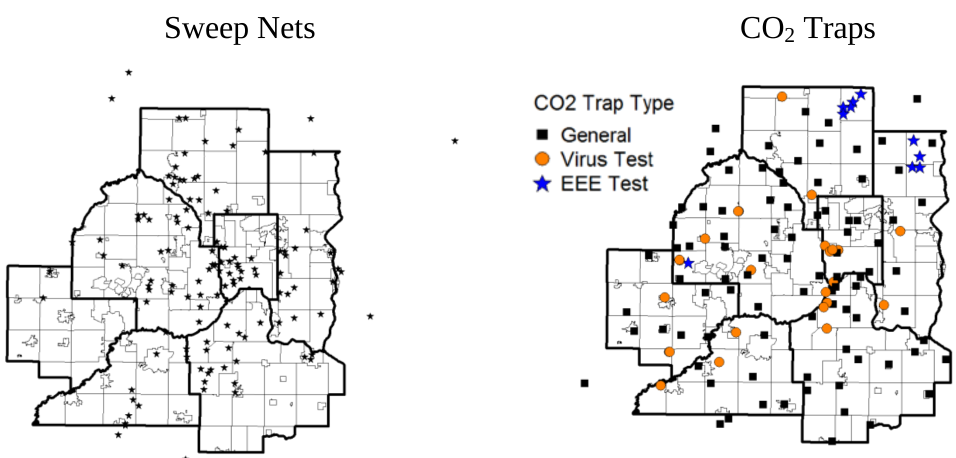


Figure 1.5 Locations of weekly sweep net and CO_2 traps locations used to monitor general mosquito populations and disease vectors (virus test and EEE test), 2016.

Sweep Net The District uses sweep net collections to monitor mosquito annoyance to humans during the peak mosquito activity period, which is 35-40 minutes after sunset for most mosquito species. The number of collectors varied from 44-105 per evening.

In 2016, staff took 1,410 collections containing 2,839 mosquitoes. The average number of summer *Aedes* collected in the evening sweep net collections was higher than in 2015, but still below the 16-year average (Table 1.2). Populations of *Cq. perturbans* were higher than the last three years and the 16-yr average. The late spring resulted in low numbers of spring *Aedes* adults, well below average. *Culex tarsalis,* which are infrequently collected in sweep net samples, were below average levels as well.

Table 1.2 Average number of mosquitoes collected per evening sweep net collection within the District, 2012-2016 and 16-year average, 2000-2015 (±SE)

Year	Summer *Aedes*	*Cq. perturbans*	Spring *Aedes*	*Cx. tarsalis*
2012	1.63	0.75	0.02	0.004
2013	1.87	0.12	0.03	0.005
2014	2.33	0.12	0.20	0.008
2015	1.27	0.29	0.05	0.006
2016	1.55	0.37	0.03	0.005
16-yr Avg.	1.86 (±0.09)	0.33 (±0.01)	0.12 (±0.01)	0.009 (±0.0004)

CO_2 Trap CO_2 traps baited with dry ice are used to monitor host-seeking mosquitoes and the presence of disease vector species. The standard placement for these traps is approximately 5 ft off the ground, the level where *Aedes* mosquitoes fly. In 2016, we placed 134 traps at 121 locations to allow maximum coverage of the District (Figure 1.5). The “General” trap type locations are used to monitor non-vector mosquitoes. There are thirteen locations with low traps (~5 ft above ground) paired with elevated traps placed in the tree canopy (~25 ft above ground) to collect *Culex* species, which are active where birds are resting. All *Culex* specimens collected from 45 traps are tested for WNV (Figure 1.5, “Virus Test” trap type). Additionally, *Cx. tarsalis* from all locations are tested. Eleven trap locations in the network have historically captured *Cs. melanura*, and are used to monitor this vector’s populations and to obtain specimens for EEE testing (Figure 1.5, “EEE Test” trap type).

A total of 2,132 trap collections taken contained 571,212 mosquitoes in 2016. The total number of traps operated per night varied from 98-111. Summer *Aedes* was the predominant species collected in CO_2 traps. Populations in 2016 were higher than 2015, lower than any of the three years prior to 2015, and slightly below the 16-year average (Table 1.3). *Coquillettidia perturbans* populations have been increasing since 2012 and were above the 16-year average. Spring *Aedes* were at the lowest level since 2004, well below the long term average. *Culex tarsalis* numbers were up slightly this year, but still below average, and are discussed later in the vector surveillance section of this chapter.

Table 1.3 Average numbers of mosquitoes collected in CO_2 traps within the District, 2012-2016 and 16-year average, 2000-2015 (± 1 SE)

Year	Summer *Aedes*	*Cq. perturbans*	Spring *Aedes*	*Cx. tarsalis*
2012	215.8	68.0	2.3	1.0
2013	303.6	22.5	5.7	2.4
2014	255.4	22.4	7.9	1.9
2015	115.7	37.4	1.7	1.0
2016	207.6	51.0	1.3	1.4
16-yr Avg.	213.9 (±33.9)	47.5 (±7.1)	8.8 (±2.2)	2.0 (±0.2)

Geographic Distribution The weekly geographic distributions of the three major groups of nuisance mosquitoes (i.e., spring *Aedes*, summer *Aedes*, and *Cq. perturbans*) collected in CO_2 traps are displayed in Figures 1.6, 1.7, and 1.8. The computer software interpolates the data between collection points, so some dark areas are the result of one collection without another close by. What little populations of spring *Aedes* we had were confined to a few locations on the outer edges of the District or in localized areas (Figure 1.6). Summer *Aedes* were collected at above threshold levels (≥130mosquitoes/trap night) in some scattered locations throughout the season, but August had the highest District-wide populations of the season (Figure 1.7). The one generation of *Cq. perturbans* occurred in their usual hot spots in the northern District borders and in Carver, Scott, and Hennepin counties (Figure 1.8).

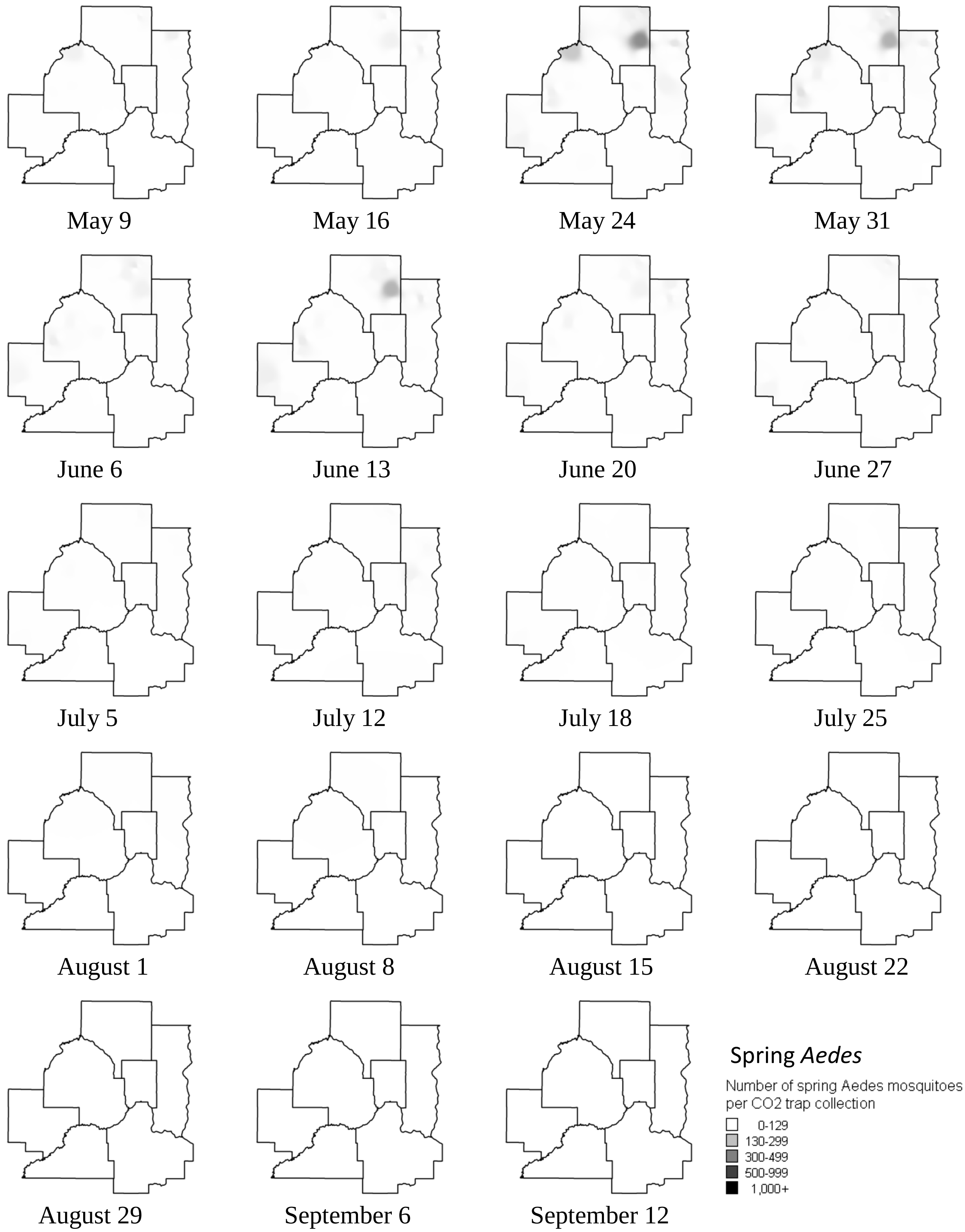


Figure 1.6 Number of spring *Aedes* in District low (5 ft) CO_2 trap collections, 2016. The number of traps operated per night varied from 98-111. Inverse distance weighting was the algorithm used for shading of maps. Treatment threshold is $\geq$130 mosquitoes/trap night.

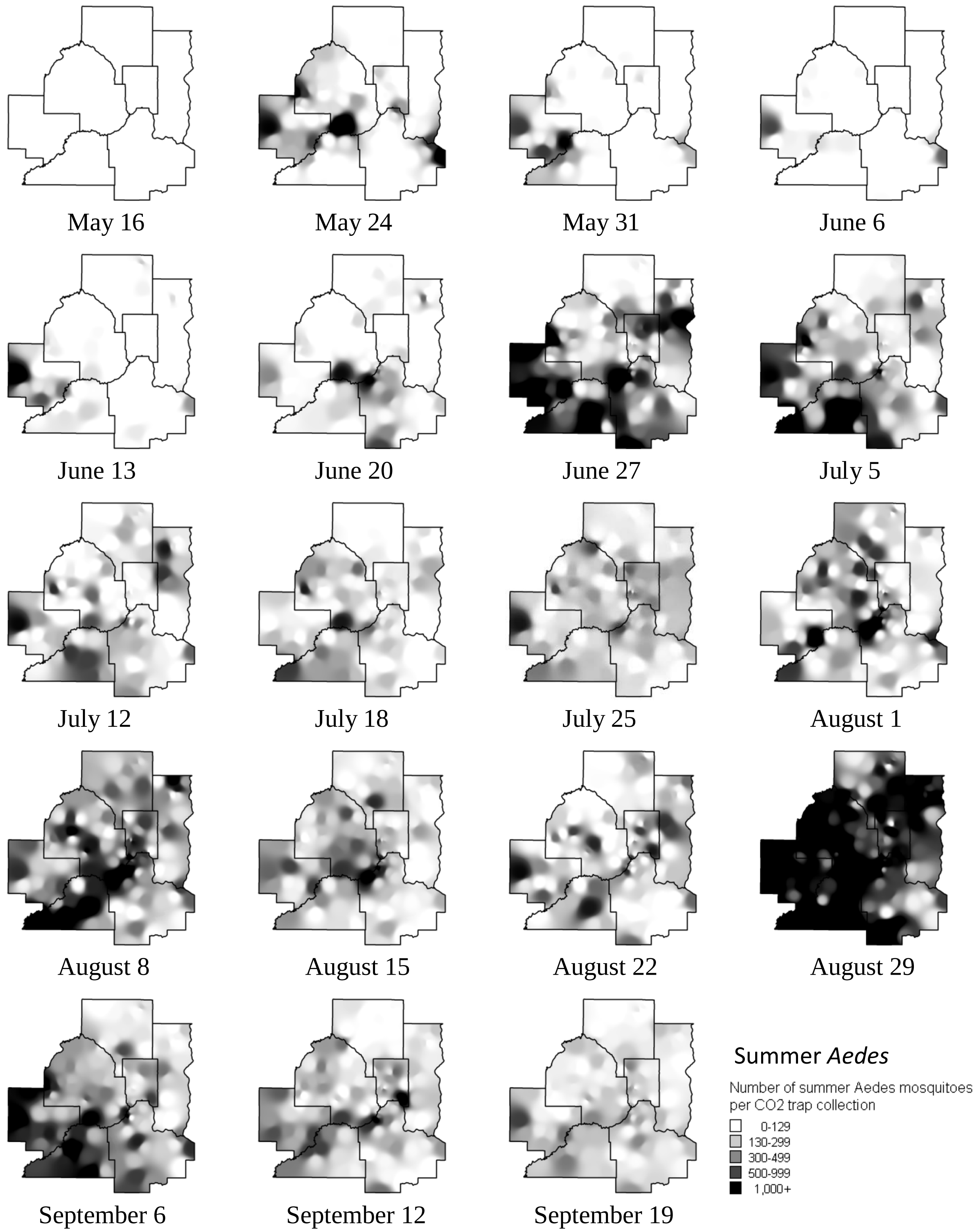


Figure 1.7 Number of summer *Aedes* in District low (5 ft) CO_2 trap collections, 2016. The number of traps operated per night varied from 98-111. Inverse distance weighting was the algorithm used for shading of maps. Treatment threshold is $\geq$130 mosquitoes/trap night.

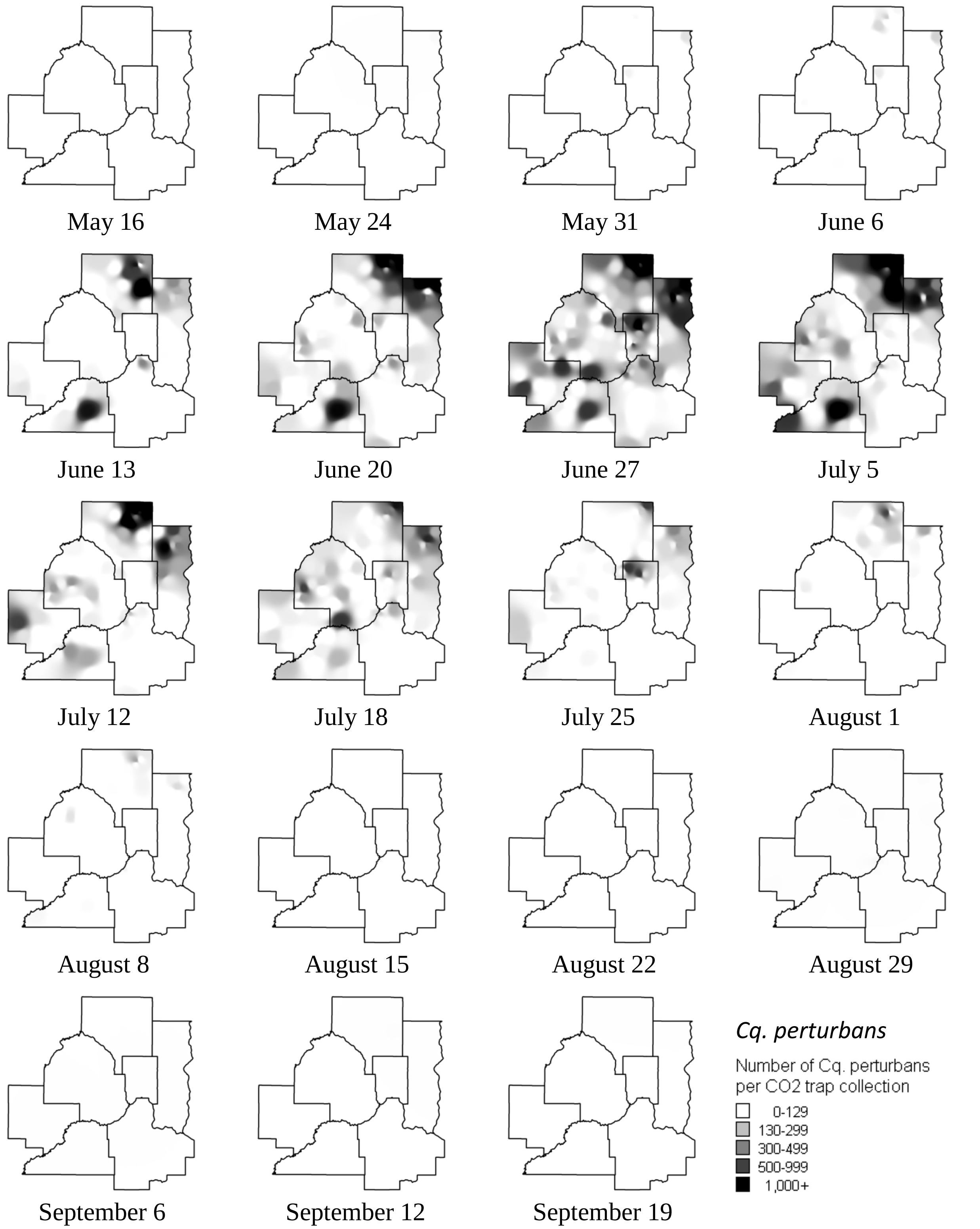


Figure 1.8 Number of *Cq. perturbans* in District low (5 ft) CO_2 trap collections, 2016. The number of traps operated per night varied from 98-111. Inverse distance weighting was the algorithm used for shading of maps. Treatment threshold is $\geq$130 mosquitoes/trap night.

Seasonal Distribution As described earlier, spring *Aedes*, summer *Aedes,* and *Cq. perturbans* have different patterns of occurrence during the season based on their phenology and the surveillance method used. Additionally, temperatures below 55 °F inhibit mosquito flight activity. Sampling with CO_2 traps and sweep nets typically begins the second week of May. The start of sweep net collections was postponed until May 24 due to very cool temperatures at the designated sweep net time (Fig. 1.9). CO_2 traps operated starting on May 9 to detect any mosquito activity that may have occurred during the warmer hours of their operation overnight. The first two nights were the only cool nights during the season that may have affected mosquito activity.

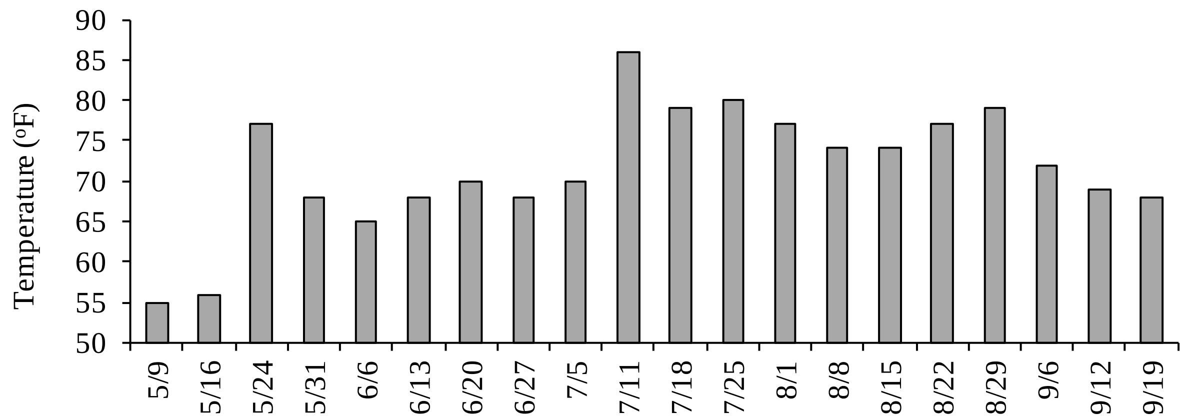


Figure 1.9 Temperature at 9:00 P.M. on actual dates of Monday night surveillance, 2016.

Figure 1.10 shows the seasonal distribution of the three major groups of mosquitoes from mid-May through early September, detected by sweep netting and CO_2 traps. Sweep nets and CO_2 traps detected the peak of spring *Aedes* activity differently. Typically, spring *Aedes* numbers peak in late May. In 2016, the peak number in sweep nets occurred on June 3 and on May 24 in CO_2 traps (Figure 1.10). Spring *Aedes* populations were well below the 10-year average and, like the sweep net detections, were present only through the end of July.

Summer *Aedes* populations were below average for most of the summer, with higher numbers detected in late July, but then came August. The sweep nets and CO_2 traps detected an unusually late season peak of summer *Aedes* levels on August 29. Mosquitoes continued to be slightly above average in September until sampling ended.

The peak for the one generation of *Cq. perturbans* occurred on June 27, a week earlier than its typical date near July 4. The peak coincided with the elevated captures of summer *Aedes* in CO_2 traps. Populations of *Cq. perturbans* remained near the 10-year average for the rest of its season, diminishing by August 8.

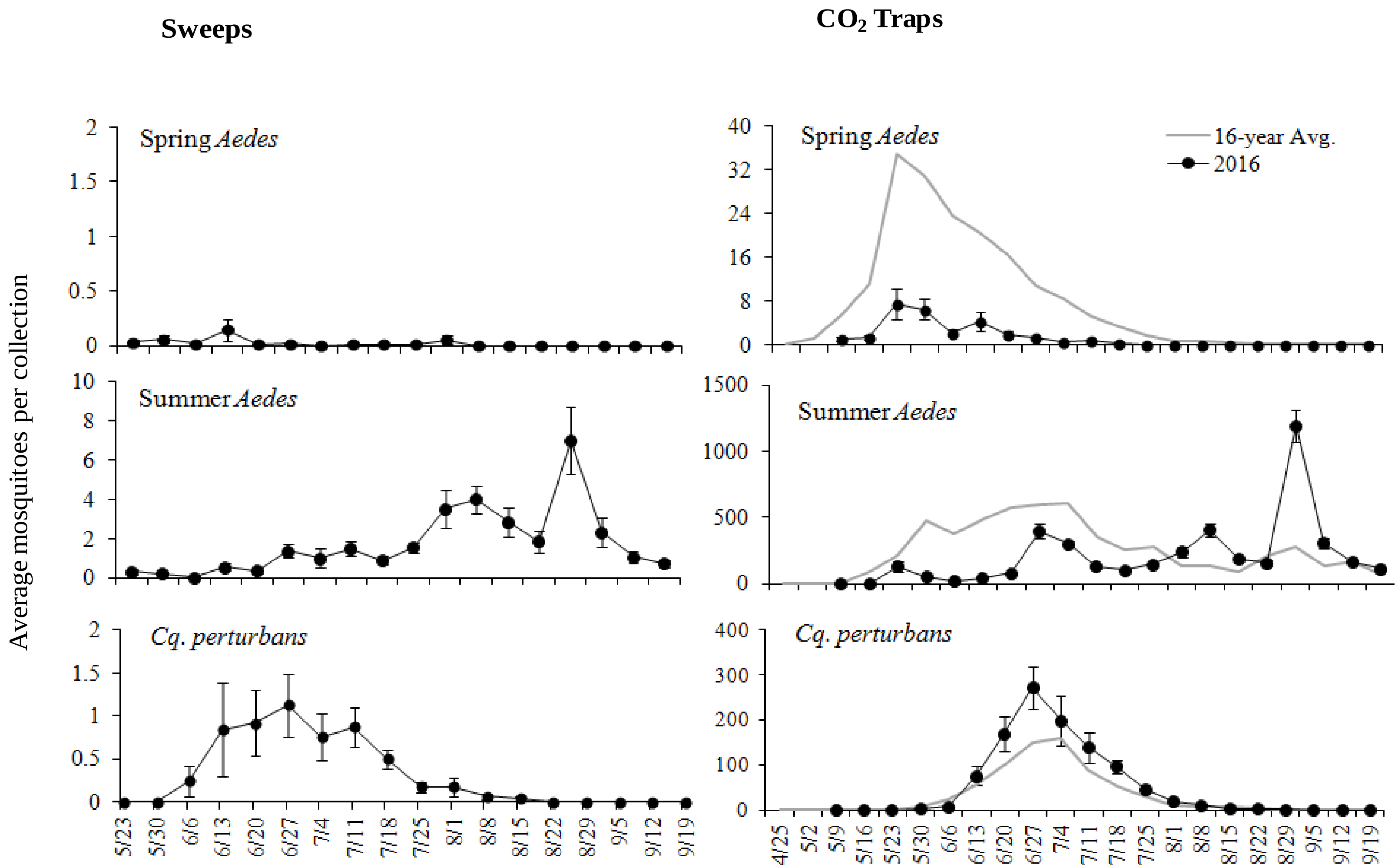


Fig. 1.10 Average number of spring *Aedes*, summer *Aedes*, and *Cq. perturbans* per sweep net, 2016 and CO_2 trap, 2016 vs. 10-year average. Dates are the Mondays of each week. Sweep sampling started the week of May 23, CO_2 traps started the week of May 9. Error bars equal $\pm$ 1 standard error of the mean.

Coquillettidia perturbans, the cattail mosquito, is usually our second-most numerous species and has one generation per year. Adults lay their eggs in cattail marshes in July and August, the eggs hatch, larvae overwinter in the marsh, and adults emerge the following June-July. Adult populations are influenced by rainfall amounts from the previous year. Higher *Cq. perturbans* captures in CO_2 traps occurred (2003, 2006, 2011, and 2012) following years with high rainfall amounts (Fig. 1.11). However, high rainfall in 2014 did not result in significantly higher *Cq. perturbans* populations in 2015. Drought conditions existed in the fall through winter of 2012-2014. Despite the heavy summer rains in 2014, water levels remained low in cattail marshes, reducing mosquito production in 2015. High rain amounts in 2015, especially in the fall, helped marshes rebound from the drought and increase mosquito production in 2016. The record-breaking amount and late summer timing of the rain in 2016 could be an indication of increased *Cq. perturbans* in 2017.

Analysis by Dr. Roger Moon (University of MN) showed the change in average *Cq. perturbans* levels (N) from a given year (t) to the next was related to the number of adults and average weekly total rainfall in the starting year$_t$ as $\text{Log}_{10}(N_{t+1}) = \text{Log}_{10}(N_t) + (0.612 - 0.913*\text{Log}_{10}(N_t) + 0.043*\text{Rain}_t)$ (Fig 1.12). This equation indicates expected catch rates in 2017 will be 91.4 *Cq. perturbans* per CO_2 trap, levels higher than experienced in the last five years (Fig. 1.11).

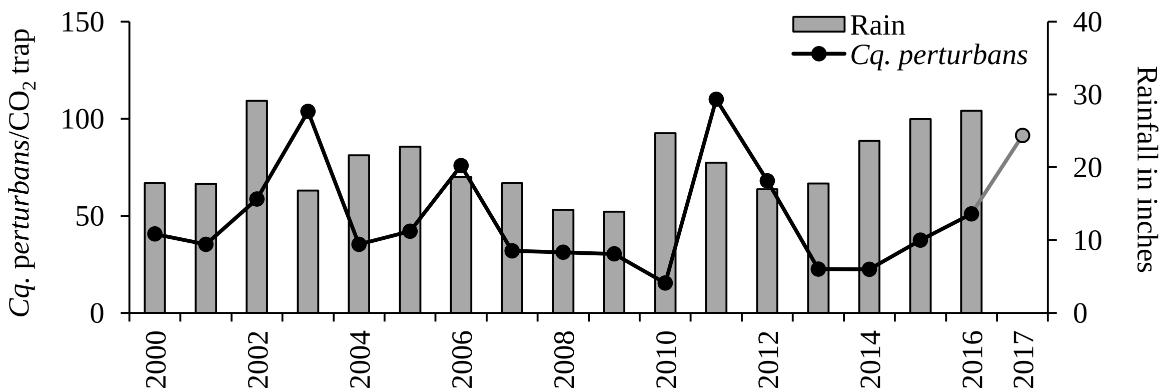


Fig. 1.11 Average number of *Coquillettidia perturbans* in CO_2 traps and average seasonal rainfall per gauge, 2000-2016, and 2017 predicted *Cq. perturbans*.

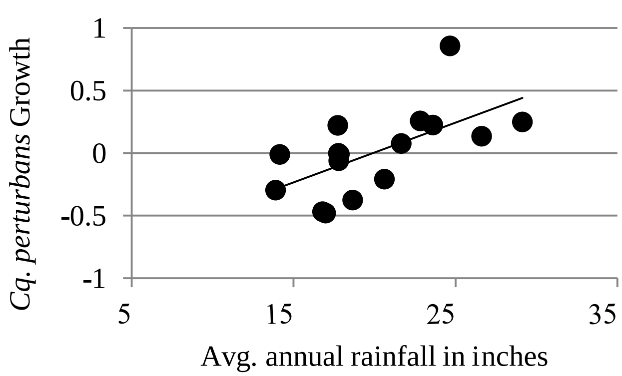


Fig. 1.12 Growth ($\text{LogN}_{t+1}/\text{N}_t$) of *Cq. perturbans* vs. average annual rainfall, 2000-2016.

New Jersey (NJ) Traps For many years, mosquito control districts used the NJ light trap as their standard surveillance tool. The trap uses a 25-watt light bulb to attract mosquitoes and many other insects as well, making the samples messy and time-consuming to process. The number of traps used by the District has varied over the years. In the early 1980s, the District operated 29 traps. After a western equine encephalitis (WEE) outbreak in 1983, the District reduced the number to seven to alleviate the regular workload due to the shift toward disease vector processing.

The number of locations and traps has fluctuated since then. In 2015, the location for Trap 1 in St. Paul became unavailable and no alternate was found. A new St. Paul location was established in 2016 at the State Fairgrounds (SF), 13 miles from the former site. The trap at the Minnesota Zoo in Apple Valley (AV) also needed to be moved one half mile to a new location within the zoo. The remaining five traps were in the following locations: trap 9 in Lake Elmo, trap 13 in Jordan, trap 16 in Lino Lakes, trap CA1 in the Carlos Avery State Wildlife Management Area, and trap MN in Minnetrista (Figure 1.13).

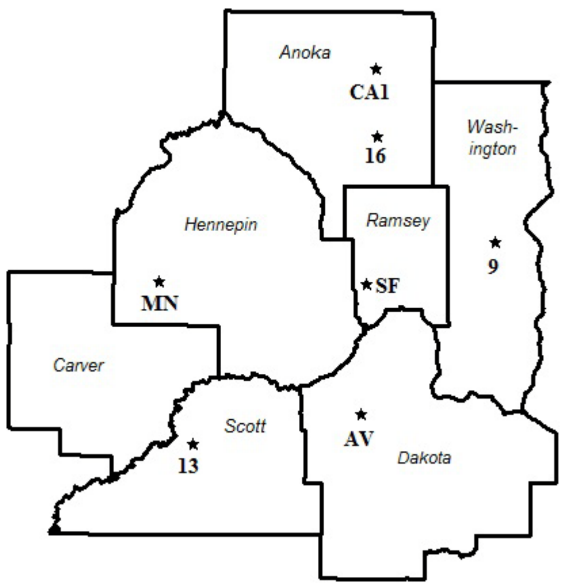


Fig. 1.13 NJ light trap locations, 2016

Trapping occurs nightly for 20 weeks from May through September and staff identify all adult female mosquitoes to species. Traps 1, 9, 13, and 16 have operated from 1965-2014. A comparison of the major species collected from those four traps is shown in Appendix B. Since the loss of Trap 1 in 2015, data displayed in Appendix B going forward will be from the remaining three long-term traps.

The most numerous species collected was *Ae. vexans* whose total was 66% of all female mosquitoes captured (Table 1.4). The Minnestrista trap contributed 66% and the Carlos Avery trap comprised 25% of all *Ae. vexans* captured. *Coquillettidia perturbans* ranked second and comprised 26% of the females captured. The Carlos Avery trap, placed within many acres of untreatable cattail habitat, contributed 79% of the overall *Cq. perturbans* collected. The hard to distinguish spring *Aedes* species combo of *Ae. abserratus* and *Ae. punctor* was in third place. Nearly all of these species (82%) were collected in the Carlos Avery trap. The summer species, *Ae. trivittatus*, was the winner of fourth place. The West Nile virus vector, *Cx. restuans*, was quite abundant this year in fifth place. The new SF location contributed over half of the *Cx. restuans* and almost all of the *Cx. pipiens* collected in 2016. *Aedes cinereus*, which occurs in the spring and summer and is usually in the top five, came in sixth place at 0.40% of the female total.

The first collection of *Ae. japonicus* in a NJ light trap was in 2009 (Minnetrista). Since then, *Ae. japonicus* has increased in frequency of occurrence and has been found at all of the NJ trap locations except Jordan. In 2016, a record total number was collected from all *Ae. japonicus*-positive NJ trap locations: Lake Elmo (23%), Minnetrista (73%), and 1% in the remaining four traps.

Table 1.4 Total numbers and frequency of occurrence for each species collected in New Jersey light traps, May 7 - September 23, 2016

	Trap Code, Location, and Number of Collections							Summary Statistics		
	SF State Fair	9 Lake Elmo	13 Jordan	16 Lino Lakes	CA1 Carlos Avery	AV Apple Valley	MN Minnetrista	Total Collected	% Female Total	Avg per Night
Species	136	120	137	96	129	140	131	889		
Ae. abserratus	0	0	0	1	235	0	2	238	0.15%	0.27
atropalpus	0	0	0	0	0	0	0	0	0.00%	0.00
aurifer	0	0	0	0	0	0	0	0	0.00%	0.00
canadensis	0	0	0	0	2	0	0	2	0.00%	0.00
cinereus	8	1	1	10	211	0	382	613	0.40%	0.69
dorsalis	0	0	1	0	0	0	0	1	0.00%	0.00
excrucians	0	0	0	0	0	0	7	7	0.00%	0.01
fitchii	0	0	0	0	1	0	1	2	0.00%	0.00
hendersoni	0	0	0	0	0	0	1	1	0.00%	0.00
implicatus	0	0	0	0	0	0	0	0	0.00%	0.00
japonicus	1	25	0	1	1	1	79	108	0.07%	0.12
nigromaculus	0	0	0	0	0	0	0	0	0.00%	0.00
punctor	0	0	0	0	70	0	0	70	0.05%	0.08
riparius	0	0	0	0	0	0	12	12	0.01%	0.01
spencerii	0	0	0	0	0	0	0	0	0.00%	0.00
sticticus	0	1	4	0	4	1	10	20	0.01%	0.02
stimulans	0	0	0	0	0	0	9	9	0.01%	0.01
provocans	0	0	0	0	0	0	0	0	0.00%	0.00
triseriatus	0	22	1	0	5	2	31	61	0.04%	0.07
trivittatus	1	440	69	7	449	35	241	1,242	0.81%	1.40
vexans	542	2,461	3,380	2,515	25,853	200	66,610	101,561	65.98%	114.24
abserratus/punctor	0	372	0	3	1,409	0	8	1,792	1.16%	2.02
Aedes species	2	23	13	11	721	2	1,269	2,041	1.33%	2.30
Spring *Aedes*	0	0	0	1	1	1	29	32	0.02%	0.04
Summer *Aedes*	22	16	0	1	0	1	21	61	0.04%	0.07
An. barberi	0	0	0	0	0	0	2	2	0.00%	0.00
earlei	0	0	0	0	1	0	0	1	0.00%	0.00
punctipennis	5	53	31	4	108	1	395	597	0.39%	0.67
quadrimaculatus	3	146	120	6	108	1	179	563	0.37%	0.63
walkeri	0	9	21	7	396	1	7	441	0.29%	0.50
An. species	0	5	4	1	59	0	53	122	0.08%	0.14
Cx. erraticus	0	0	0	0	0	0	0	0	0.00%	0.00
pipiens	102	5	5	0	0	0	2	114	0.07%	0.13
restuans	459	51	7	26	119	18	120	800	0.52%	0.90
salinarius	1	1	1	1	2	0	5	11	0.01%	0.01
tarsalis	31	4	8	9	39	0	14	105	0.07%	0.12
territans	25	13	5	12	81	24	228	388	0.25%	0.44
Cx. species	35	19	0	5	11	3	81	154	0.10%	0.17
Cx. pipiens/restuans	170	33	5	10	102	0	172	492	0.32%	0.55
Cs. inornata	4	12	4	0	8	1	42	71	0.05%	0.08
melanura	0	0	0	0	4	0	1	5	0.00%	0.01
minnesotae	11	0	3	6	56	1	3	80	0.05%	0.09
morsitans	6	1	0	1	17	1	6	32	0.02%	0.04
Cs. species	1	0	1	1	2	0	3	8	0.01%	0.01
Cq. perturbans	49	722	99	872	32,273	39	6,204	40,258	26.15%	45.28
Or. signifera	0	0	0	0	0	0	0	0	0.00%	0.00
Ps. ferox	0	1	0	0	0	0	0	1	0.00%	0.00
horrida	0	0	0	0	1	0	0	1	0.00%	0.00
Ps. species	0	2	0	0	0	0	0	2	0.00%	0.00
Ur. sapphirina	28	43	5	6	27	3	386	498	0.32%	0.56
Unidentifiable	1	10	4	4	356	1	940	1,316	0.85%	1.48
Female Total	1,507	4,491	3,792	3,521	62,732	337	77,555	153,935	100.00%	173.16
Male Total	786	1,667	1,523	1,171	15,764	87	20,774	41,772		
Grand Total	2,293	6,158	5,315	4,692	78,496	424	98,329	195,707		

Rare Detections *Culex erraticus*, considered rare in the District, was first detected in NJ traps in 1988. This species occurred sporadically since then in low numbers and in recent years has been collected in CO_2 traps more frequently (Fig. 1.14). In 2012, we were surprised to collect them in extremely high numbers throughout the District. In 2013, we were just as surprised to collect them in such low numbers. Very few were collected in last four years, with the highest number of 19 in 2015. Their name is truly descriptive of their occurrence. The reason for the 2012 peak remains a mystery. *Culex erraticus* is common in southern United States, with the District at the northern edge of its range. The unusually warm spring and summer in 2012 may have resulted in favorable conditions conducive to their large population expansion. Because *Cx. erraticus* is usually extremely rare, it has not been targeted for control. It is, however, a competent vector of eastern equine encephalitis and a suspected maintenance vector of West Nile virus, so it is still a concern.

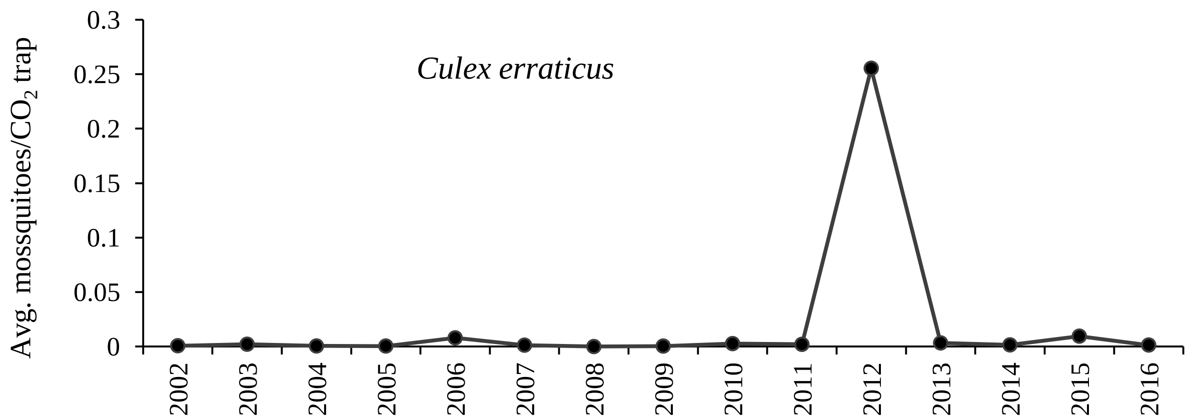


Fig. 1.14 Average yearly *Culex erraticus* in CO_2 traps, 2002-2016.

Anopheles quadrimaculatus is notable because it is a WNV maintenance vector and capable of transmitting dog heartworm and malaria. Historically, it is rare in the District, but in recent years, it has occurred in traps throughout the District more frequently than in the past (Fig. 1.15). Since 2002, *An. quadrimaculatus* has appeared with increasing frequency, reaching the highest amount ever in 2012, down slightly in 2013, very low in 2014 and 2015, and up again in 2016. We will continue to investigate the reasons for this fluctuation in occurrence.

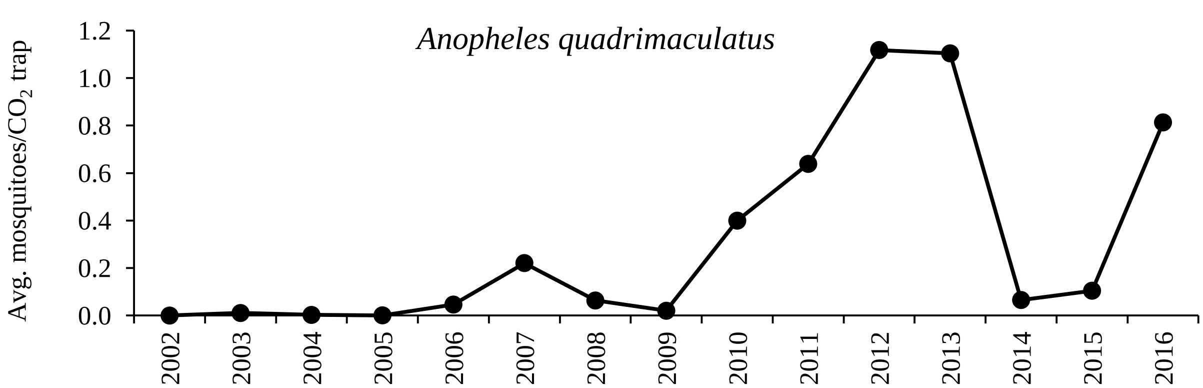


Fig. 1.15 Average yearly *Anopheles quadrimaculatus* in CO_2 traps, 2002-2016.

Psorophora species are human-biting floodwater mosquitoes that are rare in the District. Detections in NJ traps have occurred in several years since 1959, but with fewer than five mosquitoes per year. However, two species have increased in Monday night CO_2 traps since their first capture in 2006: *Ps. ferox* and *Ps. horrida* (Fig. 1.16). Specimens that are missing the taxonomic characters needed for identification to species are recorded as *Ps.* species. Several viruses have been isolated from the mosquito, but it is generally not thought to play a major role in pathogen transmission to humans. In other parts of the country, *Psorophora* is known to frequently and voraciously bite people, but only nine *Psorophora* were identified in 16 years of Monday night sweep net collections. Since southeastern Minnesota is on the northern edge of their North American ranges, it appears the *Ps. ferox* and *Ps. horrida* are expanding northward into the District. Hopefully, their low populations do not increase to the frequent and voracious biting level.

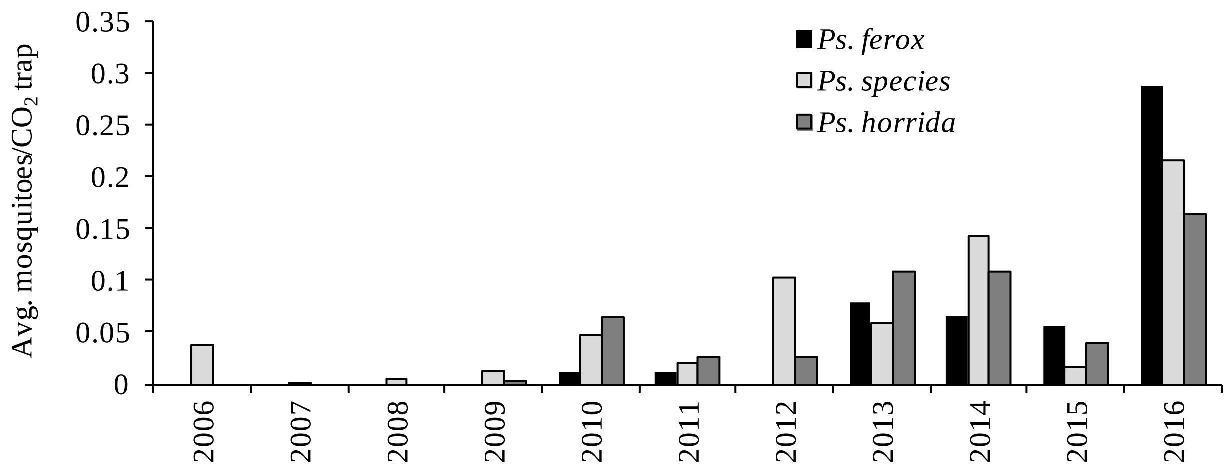


Fig. 1.16 Average yearly *Ps. ferox*, *Ps*. species and *Ps. horrida*, 2006-2016.

Targeted Vector Mosquito Surveillance

Aedes triseriatus Staff use a mechanical aspirator (pictured at left) to sample the understory for resting mosquitoes in the daytime. This method is used primarily for *Ae. triseriatus*, the La Crosse encephalitis (LAC) vector, which can be difficult to capture by other methods. The aspirator is also used to collect *Ae. japonicus* and *Ae. albopictus*, two invasive mosquito vectors. Sampling began during the week of May 16 and continued through the week of October 3.

The first collection of *Ae. triseriatus* occurred during the week of May 30 (Figure 1.17). The rate of capture in aspirators continued to climb through the week of June 27, mirroring the pattern typically observed. As was the case in 2015, the weekly mean captures of *Ae. triseriatus* remained below the multi-year average for most of 2016 even though the wet weather experienced was favorable for the species. The only week when the rate of capture exceeded the average was the week of August 15 when we observed a peak of 1.7 *Ae. triseriatus* per sample.

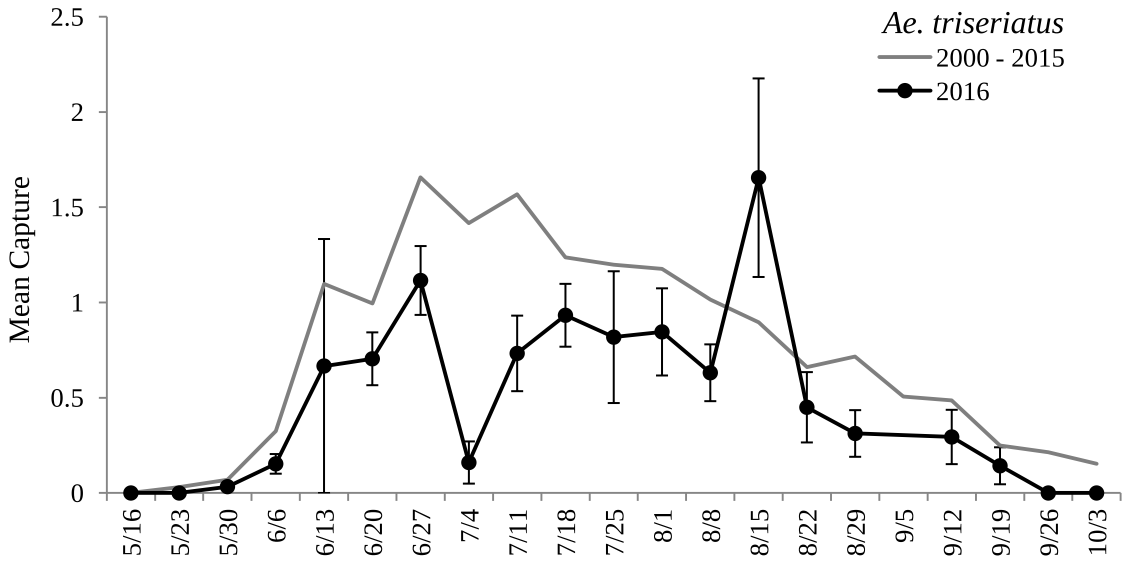


Figure 1.17 Mean number of *Ae. triseriatus* adults in 2016 aspirator samples plotted by week compared to mean captures for the corresponding weeks of 2000-2015. Dates listed are Monday of each week. There were no samples during the week of Sept. 5. Error bars equal ± 1 standard error of the mean.

Culiseta melanura *Culiseta melanura*, the enzootic vector of EEE, feeds primarily on birds. Locally, the most common larval habitat is spruce-tamarack bog or other acidic habitat. Larvae can occur in caverns in sphagnum moss supported by tree-roots. Overwintering is in the larval stage with adults emerging in late spring. There are multiple generations per year, and the late summer cohort supplies the next year's first generation. Most adults disperse a short distance from their larval habitat, although a few may fly in excess of five miles from their larval habitat.

District staff monitored adult *Cs. melanura* at 10 locations using 11 CO_2 traps. Five sites are in Anoka County, four sites are in Washington County, and one site is in Hennepin County. *Culiseta melanura* have been collected from each location in the past. Two traps are placed at the Hennepin County location – one at ground level and one elevated 25 ft into the tree canopy, where many bird species roost at night. The first *Cs. melanura* adults were collected in CO_2 traps on May 23 (Figure 1.18). The population remained low throughout the season with a maximum capture of 4.2 per trap on August 22.

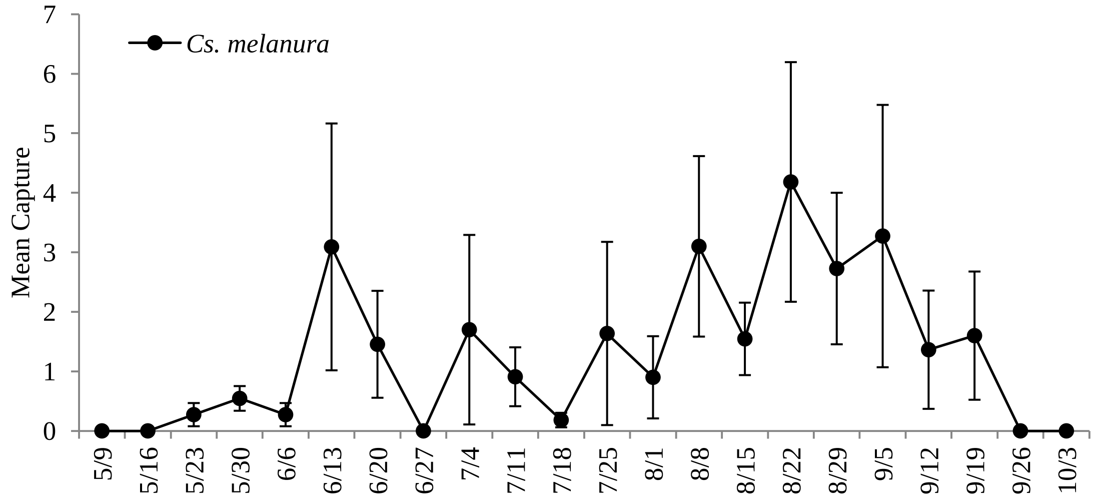


Figure 1.18 Mean number of *Cs. melanura* adults in CO_2 traps from selected sites, 2016. Dates listed are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

Staff collected 98 *Cs. melanura* in 94 aspirator samples from wooded areas near bog habitats. The first aspirator collections of *Cs. melanura* occurred during the week of June 20. Thereafter, aspirator samples targeting the species were collect during only six of the next 11 weeks. The peak rate of capture was 2.0 *Cs. melanura* per sample during the week of August 29.

***Culex* Species** *Culex* species are important for the amplification and transmission of WNV and WEE virus in our area. The District uses CO_2 traps to monitor host-seeking *Culex* mosquitoes and gravid traps to monitor egg-laying *Culex* mosquitoes. Many *Culex* specimens collected in the network were tested for WNV.

Culex tarsalis is the most likely vector of WNV for human exposures in our area and as such, they are routinely tested for WNV (see Chapter 2, Table 2.3). Collections of *Cx. tarsalis* in CO_2 traps were consistently low in 2016. The weekly mean capture peaked at 5.2 per sample during the week of August 8 (Figure 1.19). As is typical, few *Cx. tarsalis* were captured by gravid trap.

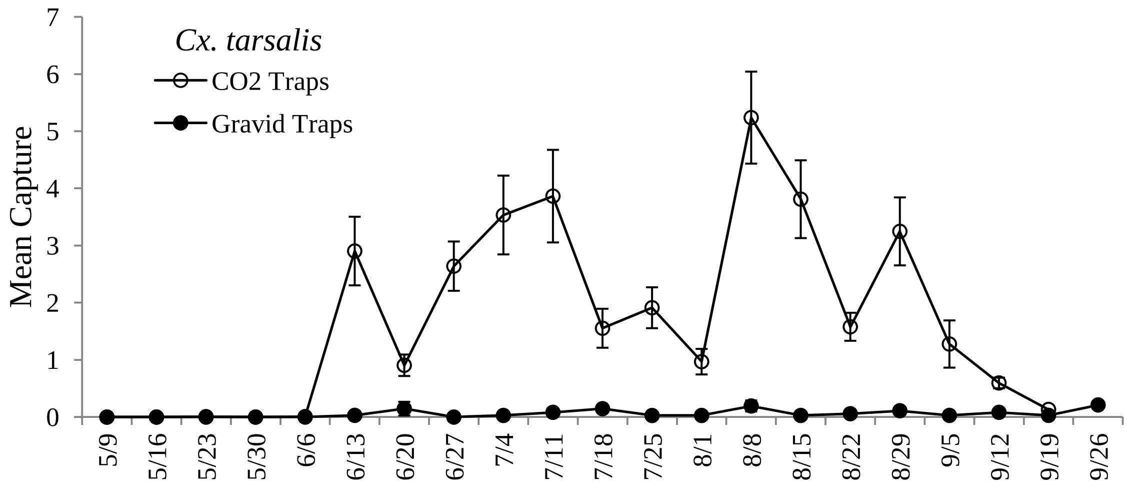


Figure 1.19 Average number of *Cx. tarsalis* in CO_2 traps and gravid traps, 2016. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

Culex restuans is another important vector of WNV in Minnesota. The species is largely responsible for the early season amplification of the virus and for season-long maintenance of the WNV cycle, as well. Low numbers of *Cx. restuans* were collected in CO_2 traps in 2016 (Figure 1.20). The CO_2 trap captures peaked on August 29 at 2.0 per trap. Gravid trap collections of *Cx. restuans* were in the low to moderate range in 2016. A modest population increase occurred in the middle of June, represented by the peak capture of 14.3 per gravid trap during the week of June 20.

Culex pipiens have been important as vectors of WNV in much of the United States. The species prefers warmer temperatures than *Cx. restuans*; therefore, populations of *Cx. pipiens* in the District tend to remain low in early to mid-summer and peak late in the summer when temperatures are typically warmer. Above average temperatures for much of June, July and August favored *Cx. pipiens* population growth in 2016. They were collected regularly in both CO_2 traps and gravid traps from the week of June 20 through the end of the season (Figure 1.21). The rate of capture peaked at 6.3 per gravid trap during the week of August 1 and at 2.6 per CO_2 trap during the week of August 15.

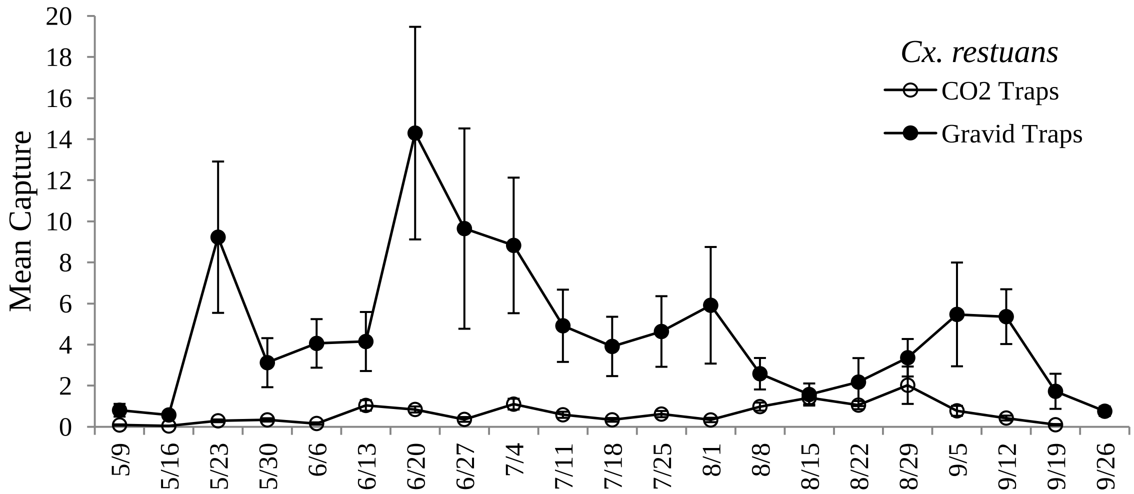


Figure 1.20 Average number of *Cx. restuans* in CO_2 traps and gravid traps, 2016. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

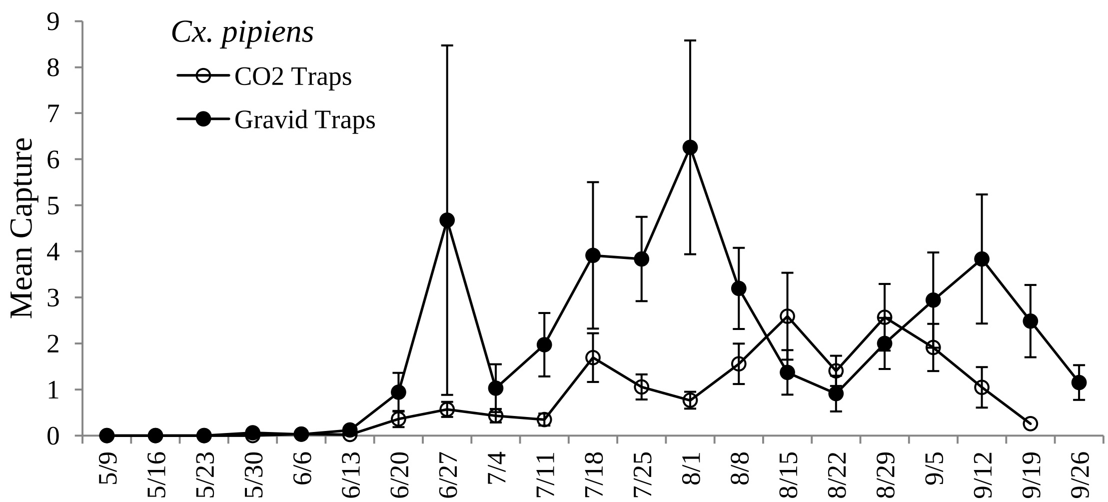


Figure 1.21 Average number of *Cx. pipiens* in CO_2 traps and gravid traps, 2016. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

When *Cx. pipiens* and *Cx. restuans* are difficult to distinguish from each other, they are grouped together and identified as *Cx. pipiens/restuans* (Figure 1.22); when only a genus level identification can be made, they are classified as *Culex* species (Figure 1.23). Both groups usually consist largely of *Cx. restuans* during the early and middle portions of the season with *Cx. pipiens* contributing more to the collections during the middle and later portions of the season.

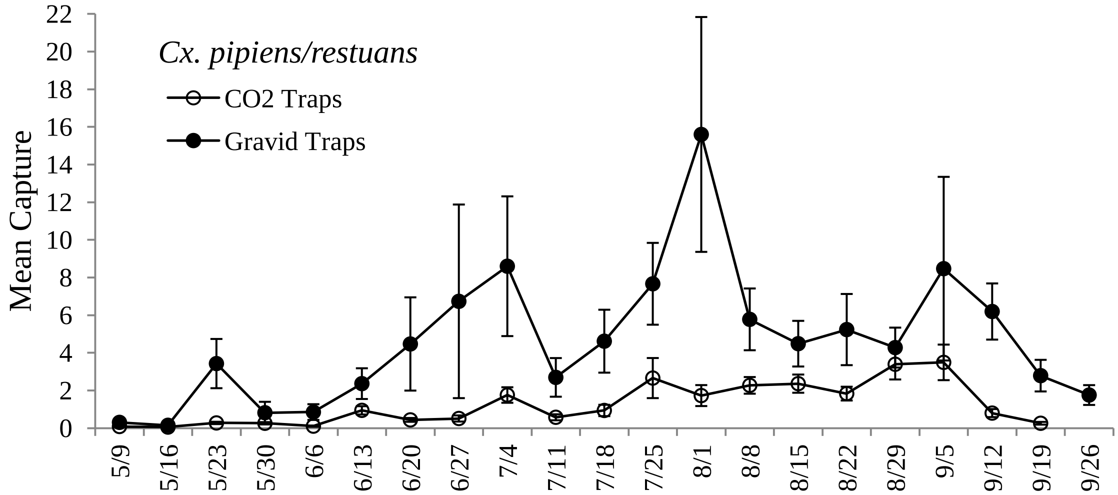


Figure 1.22 Average number of *Cx. pipiens/restuans* in CO_2 traps and gravid traps, 2016. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

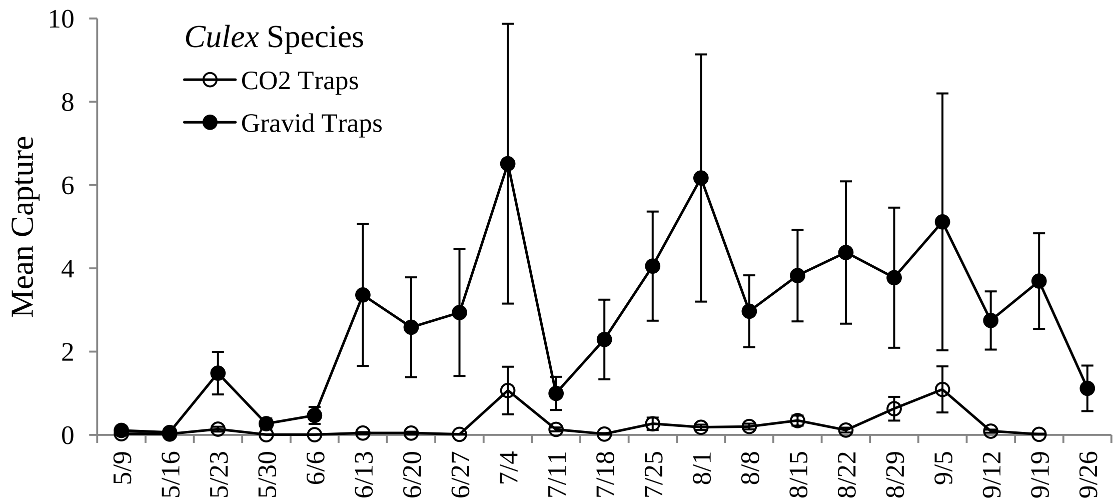


Figure 1.23 Average number of *Culex* species in CO_2 traps and gravid traps, 2016. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean

Exotic Species Each season, MMCD conducts surveillance for exotic or introduced mosquito species. There are also opportunities to collect unexpected species through a variety of surveillance techniques used to monitor local mosquito species. MMCD laboratory technicians are trained to recognize exotic species in their adult and larval forms so that the mosquitoes can be spotted in any of the tens of thousands of samples processed each year. The two exotic, invasive species most likely to be found here are *Ae. albopictus* and *Ae. japonicus*. Both are native to Asia and have adapted to use artificial larval habitats such as tires and other containers and are easily transported as eggs or larvae. *Aedes albopictus*, first collected in the US in 1985, are established in many states south and east of Minnesota and are occasionally introduced to the District in shipments of used tires or by transport of other water-holding containers. *Aedes japonicus* were first collected in the eastern United States in 1998, and were first found in the District in 2007. They are now commonly collected throughout the District.

Aedes albopictus *Aedes albopictus* were collected in 26 samples in 2016. All of the samples were collected from a tire recycling facility or adjacent properties in Scott County. Specimens were reared from 15 ovitrap samples; the first was collected on June 28, two were collected in July, five in August and seven in September. Four samples contained adult *Ae. albopictus*: three gravid traps collected on August 10, September 14, and September 28 and one aspirator sample collected on August 1. Seven larval samples from container (4) and tire (3) habitats contained *Ae. albopictus*; the first was collected on July 15, four were collected on August 3 and two were collected on November 11, which is the latest the species has ever been found in the District.

This was the fourteenth year and fifth consecutive year when *Ae. albopictus* were collected by MMCD staff, the first was 1991. *Aedes albopictus* have been found in four Minnesota counties: Carver, Dakota, Scott, and Wright. The species has not successfully overwintered at any of the Minnesota locations where previously discovered.

Aedes japonicus Since their arrival in the District in 2007, *Ae. japonicus* have spread throughout the District and they are commonly found in areas with adequate habitat. The species is routinely collected through a variety of sampling methods. Our preferred surveillance methods when targeting *Ae. japonicus* are container/tire/tree hole sampling for larvae, and aspirator sampling of wooded areas for adults.

Aedes japonicus larvae were found in 749 samples. Most were from containers (447) and tires (147). Larvae were found in other habitats as well, including: stormwater structures/artificial ponds (65), wetlands (29), catch basins (29), and tree holes (2). There were 30 *Ae. japonicus* samples from unspecified larval habitats. The frequency of *Ae. japonicus* occurrence in larval samples from containers and tires has increased each year since their arrival in the District with one exception (2013); the species is found less commonly in tree holes (Table 1.5).

Table 1.5 Percentage of samples from containers, tires, and tree holes containing *Ae. japonicus* larvae, 2009 – 2016

	Percent in habitat types		
Year	Containers	Tires	Tree holes
2009	4.2	2.9	0.0
2010	23.5	15.5	8.8
2011	36.2	21.3	9.3
2012	39.4	26.7	4.7
2013	35.7	21.2	1.8
2014	39.2	26.3	2.0
2015	44.2	36.0	4.8
2016	47.9	42.7	4.5

Aedes japonicus adults were identified in 528 samples. They were found in 251 aspirator samples, 112 gravid trap samples, 71 CO_2 trap samples, 47 NJ trap samples, and 47 two-minute sweep samples. *Aedes japonicus* were also hatched from 34 of 58 ovitrap samples collected in 2016.

2017 Plans – Surveillance

Surveillance will continue as in past years with possible adjustments to monitor disease vectors in the District. We will evaluate sweep net, CO_2, and gravid trap locations to ensure adequate distribution and that target species are collected.

Chapter 2 Vector-borne Disease

2016 Highlights

- There were three La Crosse encephalitis cases in Minnesota, with one in the District
- WNV illnesses were confirmed in 79 Minnesotans, 14 occurred in District residents
- WNV detected in 51 District mosquito samples
- Collected and recycled 18,417 tires
- Record 82 of 100 sites *I. scapularis* positive
- Average *I. scapularis* per mammal (1.68), a new record high
- *Amblyomma americanum* 0 reports MMCD, 2 reports MDH- 1 each in Wabasha and Dakota counties
- 2016 tick-borne cases not available (source MDH), but in 2015 Lyme cases totaled 1,176 and HA cases totaled 613

Background

District staff provides a variety of disease surveillance and control services, as well as public education, to reduce the risk of mosquito-borne illnesses such as La Crosse encephalitis (LAC), western equine encephalitis (WEE), eastern equine encephalitis (EEE), and West Nile (WNV) encephalitis, as well as tick-borne illnesses such as Lyme disease and human granulocytic anaplasmosis (HGA). Past efforts have also included determining metro-area risk for infections of Jamestown Canyon virus (JC), babesiosis, Rocky Mountain spotted fever, and Sin Nombre virus (a Hantavirus).

La Crosse encephalitis prevention services were initiated in 1987 to identify areas within the District where significant risk of acquiring this disease exists. High-risk areas are defined as having high populations of the primary vector *Aedes triseriatus* (eastern tree hole mosquito), *Aedes japonicus* (Japanese rock pool mosquito) a possible vector, or a history of LAC cases. MMCD targets these areas for intensive control including public education, larval habitat removal (e.g., tires, tree holes, and containers), and limited adult mosquito treatments. Additionally, routine surveillance and control activities are conducted at past LAC case sites. Surveillance for the invasive species *Aedes albopictus* (Asian tiger mosquito) routinely occurs to detect infestations of the potential disease vector.

Culex species are vectors of WNV, a virus that arrived in Minnesota in 2002. Since then MMCD has investigated a variety of mosquito control procedures to enhance our comprehensive integrated mosquito management strategy to prevent West Nile illness. We do in-house testing of birds and mosquitoes for WNV, and use that information along with other mosquito sampling data to make mosquito control decisions.

The District collects and tests *Culex tarsalis* to monitor WNV and WEE activity. The species is a bridge vector for both viruses, meaning it bridges the gap between infected birds and humans and other mammals. Western equine encephalitis can

2017 Plans

- Continue to provide surveillance and control for La Crosse encephalitis prevention
- Continue to improve surveillance and control of *Ae. japonicus*
- Continue catch basin larvicide treatments to manage WNV vectors
- Communicate disease prevention strategies to other local governments
- Continue surveillance for WNV and other mosquito-borne viruses
- Continue to monitor for *Ae. albopictus* and other exotic species
- Continue *Cs. melanura* surveillance and evaluate control options for EEE prevention
- Continue *I. scapularis* surveillance at 100 sampling locations
- Continue with tick-borne disease education, tick identifications, and homeowner consultations
- Continue to update the Tick Risk Meter and provide updates on Facebook
- Continue to post signs at dog parks and expand to additional locations
- Continue to track collections of *A. americanum* or other new or unusual tick species
- Continue a collaborative study testing *I. scapularis* nymphs for tick-borne disease exposure

cause severe illness in horses and humans. The last WEE outbreak in Minnesota occurred in 1983.

The first occurrence of EEE in Minnesota was in 2001. Since then, MMCD has conducted surveillance for *Culiseta melanura*, which maintains the virus in birds. A "bridge vector" such as *Coquillettidia perturbans* can acquire the virus from a bird and pass it to a human in a subsequent feeding.

In 1989 the state legislature mandated the District "*to consult and cooperate with the MDH in developing management techniques to control disease vectoring ticks*." The District responded by beginning tick surveillance and forming the Lyme Disease Tick Advisory Board (LDTAB) in 1990. The LDTAB includes MMCD and Minnesota Department of Health (MDH) staff, local scientists, and agency representatives who offer their expertise to the tick-borne disease effort.

MMCD initiated tick surveillance to determine the range and abundance of the black-legged tick (*Ixodes scapularis*, also known as the deer tick) and the Lyme disease spirochete, *Borrelia burgdorferi*, within the District. To date, MMCD has mapped the current distribution of black-legged ticks (545 total sites sampled) and continues to monitor their populations in the metropolitan area. Additionally, District employees have assisted the University of Minnesota with spirochete and anaplasmosis studies. All collected data are summarized and presented to the MDH for their risk analysis.

Because wide-scale tick control is neither ecologically nor economically feasible, tick-borne disease prevention is limited to public education activities that emphasize tick-borne disease awareness and personal precautions. District employees continue to provide tick identifications upon request and are used as a tick referral resource by agencies such as the MDH and the Minnesota Department of Natural Resources (MNDNR).

As described in this and prior operational reports, MMCD uses a variety of surveillance techniques to determine the geographic distribution and estimated population levels of both mosquito and tick vectors in the metropolitan area. We continue to modify our surveillance efforts as new or different diseases and disease vectors are detected. This information is used to direct vector control and public education where needed. However, knowing the location and population levels of the vectors is only one part of the vector-borne disease cycle; understanding where vector-borne disease pathogens may be circulating is also important. Because MMCD lacks the equipment to test vectors or reservoir hosts for tick-borne and most mosquito-borne pathogens, samples are sent to MDH for testing.

In 2009, MMCD began examining ways to expand its programs to be more proactive in the area of vector-borne diseases. We contacted various agencies and held a Lyme Disease Tick Advisory Board meeting to solicit technical expertise. We would ultimately like to increase our ability to serve metro citizens given that in recent years we have received reports of rarely detected vector-borne illnesses (EEE, Powassan, Jamestown Canyon, Rocky Mountain spotted fever). Additionally, we frequently detect invasive vector species (*Ae. albopictus*, *Ae. japonicus*, *Amblyomma americanum*). *Aedes japonicus* are now established throughout the District.

2016 Mosquito-borne Disease Services

Source Reduction

Water-holding containers such as tires, buckets, tarps, and even plastic toys provide developmental habitat for many mosquito species including *Ae. triseriatus*, *Ae. albopictus*, *Ae. japonicus*, *Cx. restuans*, and *Cx. pipiens*. Eliminating these container habitats is an effective strategy for preventing mosquito-borne illnesses. In 2016, District staff recycled 18,417 tires that were collected from the field (Table 2.1). Since 1988, the District has recycled 654,756 tires. In addition, MMCD eliminated 1,690 containers and filled 261 tree holes. This reduction of larval habitats occurred while conducting a variety of mosquito, tick, and black fly surveillance and control activities, including the 1,655 property inspections by MMCD staff.

Table 2.1 Number of tire, container, and tree hole habitats eliminated during each of the past 12 seasons

Year	Tires	Containers	Tree holes	Total
2005	10,614	2,656	1,008	14,278
2006	10,513	2,059	228	12,800
2007	14,449	1,267	107	15,823
2008	16,229	1,615	93	17,937
2009	39,934	8,088	529	48,551*
2010	23,445	5,880	275	29,600
2011	17,326	3,250	219	20,795
2012	21,493	3,908	577	25,978
2013	17,812	2,410	386	20,608
2014	21,109	3,297	478	24,884
2015	24,127	2,595	268	26,990
2016	18,417	1,690	261	20,368

*Intensified property inspections in response to introduction of *Ae. japonicus*

La Crosse Encephalitis (LAC)

La Crosse encephalitis is a viral illness that is transmitted in Minnesota by *Ae. triseriatus*. *Aedes albopictus* and *Ae. japonicus* are also capable of transmitting the La Crosse virus (LACV). Small mammals such as chipmunks and squirrels are the vertebrate hosts of LACV; they amplify the virus through the summer months. The virus can also pass transovarially from one generation of mosquitoes to the next. Most cases of La Crosse encephalitis are diagnosed in children under the age of 16. In 2016, there were 34 La Crosse illnesses documented in the United States.

***Aedes triseriatus* Surveillance and Control** *Aedes triseriatus* will lay eggs in water-holding containers, but the preferred natural habitat is tree holes. MMCD staff use an aspirator to sample wooded areas in the daytime to monitor the day-active adults. Results are used to direct larval and adult control activities.

The first adult *Ae. triseriatus* were collected during the week of May 30, 2016 matching the previous season, but later than typically observed. Also similar to 2015 observations, aspirator collections of *Ae. triseriatus* were atypically low throughout most of the 2016 season (see Chapter 1, Fig. 1.15).

In 2016, MMCD staff collected 1,590 aspirator samples to monitor *Ae. triseriatus* populations. Inspections of wooded areas and surrounding residential properties to eliminate larval habitat were provided as follow-up service when *Ae. triseriatus* adults were collected. Two hundred twelve samples met the District's adulticide treatment threshold ($\geq$ 2 adult *Ae. triseriatus* per aspirator collection). Adulticides were applied to wooded areas in 83 of those cases. Adult *Ae. triseriatus* were captured in 393 of 1,268 wooded areas sampled. The mean *Ae. triseriatus* capture was similar to 2015, but lower than observed during other wet seasons (Table 2.2).

Table 2.2 *Aedes triseriatus* aspirator surveillance data, 2000 – 2016

Year	Total areas surveyed	No. with *Ae. triseriatus*	Percent with *Ae. triseriatus*	Total samples collected	Mean *Ae. triseriatus* per sample
2000	1,037	575	55.4	1,912	1.94
2001	1,222	567	46.4	2,155	1.32
2002	1,343	573	42.7	2,058	1.70
2003	1,558	470	30.2	2,676	1.20
2004	1,850	786	42.5	3,101	1.34
2005	1,993	700	35.1	2,617	0.84
2006	1,849	518	28.0	2,680	0.78
2007	1,767	402	22.8	2,345	0.42
2008	1,685	495	29.4	2,429	0.64
2009	2,258	532	24.0	3,125	0.56
2010	1,698	570	33.6	2,213	0.89
2011	1,769	566	32.0	2,563	0.83
2012	2,381	911	38.3	3,175	1.10
2013	2,359	928	39.3	2,905	1.22
2014	2,131	953	44.7	2,543	1.45
2015	1,272	403	31.7	1,631	0.72
2016	1,268	393	31.0	1,590	0.75

La Crosse Encephalitis in Minnesota There were three LAC cases reported in Minnesota in 2016. One of the cases was diagnosed in a District resident (Scott County). The others were in residents of Olmsted and Nicollet counties. Since 1970, the District has had an average of 2.2 LAC cases per year (range 0 – 10, median 2). Since 1990, the mean is 1.5 cases per year (range 0 – 8, median 1).

While *Ae. triseriatus* is known as the primary vector of LAC, the role *Ae. japonicus* might play in the LAC cycle is less understood. *Aedes japonicus* is a competent vector of LAC virus in laboratory settings. In 2016, MMCD submitted 43 pools of *Ae. japonicus* to MDH to be tested for LAC virus as well as WNV. All results were negative.

Eastern Equine Encephalitis (EEE)

Eastern equine encephalitis is a viral illness of humans, horses and some other domestic animals such as llamas, alpacas, and emus. The EEE virus circulates among mosquitoes and birds and is most common in areas near the habitat of its primary vector, *Cs. melanura*. These habitats include many coastal wetlands, and in the interior of North America, tamarack bogs and other bog sites. The first record of EEE in Minnesota was in 2001 when three horses were diagnosed with the illness, including one from Anoka County. Wildlife monitoring by the Minnesota Department of Natural Resources (MNDNR) has routinely detected antibodies to the EEE virus in wolves, moose, and elk in northern Minnesota.

In 2016, detections of the EEE virus were reported to CDC by 19 states. There were six human illnesses diagnosed: two each in Michigan and North Carolina and one each in Georgia and Montana. There were veterinary reports of EEE illnesses in domestic animals, primarily horses, from 15 states. The nearest reports of EEE activity to the District were veterinary reports of illness in Chippewa County and Eau Claire County Wisconsin.

***Culiseta melanura* Surveillance** *Culiseta melanura* are relatively rare in the District and are restricted to a few bog-type larval habitats. The greatest concentration of this type of habitat is in the northeast part of MMCD in Anoka and Washington counties. Still, *Cs. melanura* specimens are occasionally collected in other areas of the District.

The *Cs. melanura* population remained low in 2016 with a season total of only 309 adult females collected in 226 CO_2 trap settings from designated surveillance locations (see Chapter 1, Figure 1.5). Twenty-five pools containing 251 *Cs. melanura* were submitted to MDH for EEE and WNV analysis. All results were negative.

Western Equine Encephalitis (WEE)

Western equine encephalitis circulates among mosquitoes and birds in Minnesota. Occasionally, the virus causes illness in horses and less frequently in people. *Culex tarsalis* is the species most likely to transmit the virus to people and horses. In both 2004 and 2005, the virus was detected in *Cx. tarsalis* specimens collected in southern Minnesota. The virus has not been detected in Minnesota since then. *Culex tarsalis* collections remained in the low to moderate range for most of the season, peaking during the second week of August (see Ch 1, Fig. 1.18). Two hundred seventy-four samples were tested for West Nile virus in the MMCD lab using the RAMP® test. There were no pools tested for WEE. Seven pools of *Cx. tarsalis* collected between July 22 and September 2 were positive for WNV.

West Nile Virus (WNV)

West Nile virus circulates among many mosquito and bird species. It was first detected in New York in 1999 and has since spread through the continental U.S., much of Canada, Mexico, Central America, and South America. The virus causes many illnesses in humans and horses each year. West Nile virus was first detected in Minnesota in 2002. It is transmitted locally by several mosquito species, but most frequently by *Cx. tarsalis*, *Cx. pipiens*, and *Cx. restuans*.

WNV in the United States West Nile virus transmission was documented in 47 states in 2016. Alaska, Hawaii and Maine were the exceptions. The U.S. Centers for Disease Control and Prevention received reports of 2,038 West Nile illnesses from 45 states and the District of Columbia. There were 94 fatalities attributed to WNV infections. California had the greatest number of cases with 424. Adjusted for population, the highest rate of infection was in South Dakota. Nationwide screening of blood donors detected WNV in 275 individuals from 33 states. Of the 275 presumptively viremic blood donors, 36 eventually developed clinical illnesses and are also included in the confirmed cases reported to CDC.

WNV in Minnesota MDH reported 79 WNV illnesses in Minnesota residents. There were five WNV fatalities in Minnesota in 2016. There were 16 presumptively viremic blood donors reported from Minnesota. Additionally, there were 19 reports of WNV illness in horses from 16 Minnesota counties. Two wild birds from one county and 51 mosquito samples from seven counties also returned positive results for WNV.

West Nile in the District There were 14 WNV illnesses reported in residents of the District, four in Anoka County, four in Hennepin County, two in Dakota County, two in Ramsey County, one in Scott County and one in Washington County. One of the Hennepin County cases was likely exposed outside of Minnesota. Since WNV arrived in Minnesota, the District has experienced an average of 9.9 WNV illnesses each year (range 0 – 25, median 8). When cases with suspected exposure locations outside of the District are excluded, the mean is 7.6 cases per year (range 0 – 17, median 6).

Surveillance for WNV Warm weather in late May and June facilitated early season WNV amplification in 2016 and gave the virus a boost prior to July when conditions are typically more favorable for the WNV. Furthermore, the consistent pattern of rainfall throughout the 2016 season provided ample *Culex* habitat.

Several mosquito species from 42 CO_2 traps (13 elevated into the tree canopy) and 36 gravid traps were processed for viral analysis each week. In addition, we processed *Cx. tarsalis* collected by any of the CO_2 traps in our Monday night network for viral analysis. MMCD tested 795 mosquito pools using the RAMP® method, 51 of which were positive for WNV. We also submitted 70 mosquito pools to MDH for WNV analysis by PCR, none of which were positive for WNV. Table 2.3 is a complete list of mosquitoes MMCD processed for WNV analysis.

Table 2.3 Number of MMCD mosquito pools tested for West Nile virus and minimum infection rate (MIR) by species, 2016

Species	Number of mosquitoes	Number of pools	WNV+ pools	MIR per 1,000
Aedes albopictus	4	3	0	0
Aedes japonicus	327	43	0	0
Culex pipiens	797	33	0	0
Culex restuans	1,798	67	1	0.56
Culex salinarius	31	6	0	0
Culex tarsalis	3,280	274	7	2.13
Culex species	6,084	246	29	4.77
Culex pipiens/restuans	3,289	168	14	4.26
Culiseta melanura	251	25	0	0
Total	15,861	865	51	3.22

The first WNV positive result of 2016 was from a mixed pool of *Culex* species collected by a gravid trap in Coon Rapids on June 22. Seven of the 51 WNV positive mosquito pools were collections of *Cx. tarsalis*, the remaining 44 were *Cx. restuans*, mixed pools of *Cx. pipiens* and *Cx. restuans* or pools identified as *Culex* species.

Thirty-two of the 51 WNV positive mosquito samples were collected in Ramsey County. Five WNV positive samples were collected in Hennepin County, five in Dakota County, four in Scott County, two each in Anoka and Carver counties, and one was collected in Sibley County. Thirty-four of the 51 WNV positive samples were collected by gravid traps; 17 were collected by CO_2 traps.

Above average temperatures from late May through June allowed WNV to reach detectable levels before the end of June. Hot weather during the week of July 18 stimulated a rise in the WNV infection rate in mosquitoes which peaked for the season two weeks later at 7.6/1,000 *Culex* tested (Figure 2.1). The infection rate remained in the 3/1,000 to 6/1,000 range through the first week of September. The rise in Minnesota WNV infections coincided with an increase in mosquito infection rate in August. Nearly 2/3 of the state's WNV illnesses originated during the four weeks from August 1 through August 28.

Figure 2.1 Weekly minimum WNV infection rates (MIR) per 1,000 *Culex* specimens tested in 2016. Dates listed are the Monday of each sampling week.

Two birds tested by MMCD in 2016 were positive for WNV by RAMP® test. They were both American crows collected from a single Wayzata property during the week of July 11. The District modified its bird surveillance plan in 2013 for more efficient use of reported information. We determined that we would stop collecting birds after the first WNV positive result. Eighty reports of dead birds were received by telephone, internet, or from employees in the field. Eleven of the reports were of dead blue jays, 61 were American crows. All other reports were of non-corvids.

Larval *Culex* Surveillance

Culex mosquitoes lay rafts of eggs on the surface of standing water in both natural and man-made habitats. Detecting *Culex* mosquitoes can be challenging since larvae will not be present in a wet habitat unless adult, egg-laying females have been recently active, the area was wet and attractive for oviposition, and the characteristics of the site allow for survival of newly hatched mosquitoes. *Culex* are also less abundant than other types of mosquitoes in our area. Furthermore, in large wetlands larvae can disperse over a wide area or they may clump together in small, isolated pockets. They are generally easier to locate in small habitats (i.e., catch basins, stormwater management structures, etc.) where greater concentrations of larvae tend to be more evenly dispersed.

Stormwater Management Structures and Other Man Made Habitats Since 2006, MMCD field staff have been working to locate stormwater structures, evaluate habitat, and provide larval control. A classification system was devised to categorize potential habitats. Types of structures include culverts, washouts, riprap, risers (pond level regulators), underground structures, swimming pools, ornamental ponds, and intermittent streams.

Staff made 8,788 inspections of 6,529 structures in 2016. Mosquito larvae were found in 928 of the 4,395 habitats that were wet on the date of inspection. Inspectors collected 625 larval samples from stormwater structures and other constructed habitats. *Culex* vectors were found in 90.1 percent of the samples, which is higher than observed in previous seasons (Table 2.4). *Culex pipiens, Cx. restuans*, and *Cx. tarsalis* occurred about as frequently as in 2015.

Table 2.4 Frequency of *Culex* vector species in samples collected from stormwater management structures and other constructed habitats 2012 – 2016

	Yearly percent occurrence				
Species	2012 (N=1,080)	2013 (N=877)	2014 (N=814)	2015 (N=701)	2016 (N=625)
Cx. pipiens	39.8	29.8	15.6	24.4	27.4
Cx. restuans	53.1	66.0	64.6	71.0	75.4
Cx. salinarius	0.6	0.5	0.6	0.4	0.0
Cx. tarsalis	3.4	3.9	5.4	2.4	3.5
Any *Culex* vector spp.	74.5	78.6	74.1	81.6	90.1

Mosquito Control in Underground Stormwater Structures Many stormwater management systems include large underground chambers to trap sediments and other pollutants. There are several designs in use that vary in dimension and name, but collectively they are often referred to as BMPs from *Best Management Practices for Stormwater* under the US Environmental Protection Agency's National Pollution Discharge Elimination System (NPDES). MMCD has worked with city crews to survey and treat underground BMPs since 2005.

In 2016, we continued the cooperative mosquito control plan for underground habitats. Twenty municipalities volunteered their staff to assist with material applications (Table 2.5). Altosid® XR briquets were used at the label rate of one briquet per 1,500 gallons of water retained. Briquets were placed in 766 underground habitats.

Prolific mosquito development has been documented in local underground BMPs. The majority of mosquitoes found in BMPs are *Culex* species and successfully controlling their emergence from underground habitats will remain an objective in MMCD's comprehensive strategy to manage WNV vectors. We plan to continue working with municipalities to limit mosquito development in stormwater systems.

Table 2.5 Cities that assisted in treating underground stormwater habitats in 2016; 766 structures were treated and a total of 879 briquets were applied

City	Structures treated	Briquets used	City	Structures treated	Briquets used
Arden Hills	15	15	Lino Lakes	10	10
Blaine	6	21	Maplewood	195	195
Bloomington	102	119	Mendota Heights	26	34
Brooklyn Park	4	15	Minneapolis	166	166
Columbia Heights	8	12	New Brighton	5	8
Crystal	12	28	New Hope	6	12
Eagan	20	20	Richfield	13	25
Eden Prairie	12	20	Roseville	11	14
Golden Valley	132	132	Savage	18	28
Little Canada	3	3	Spring Lake Park	2	2

Larval Surveillance in Catch Basins Catch basin larval surveillance began the week of May 20 and ended the week of August 29 (Figure 2.2). Despite frequent rainfall throughout the summer, larvae were found during 456 of 628 catch basin inspections (72.6%) in 2016.

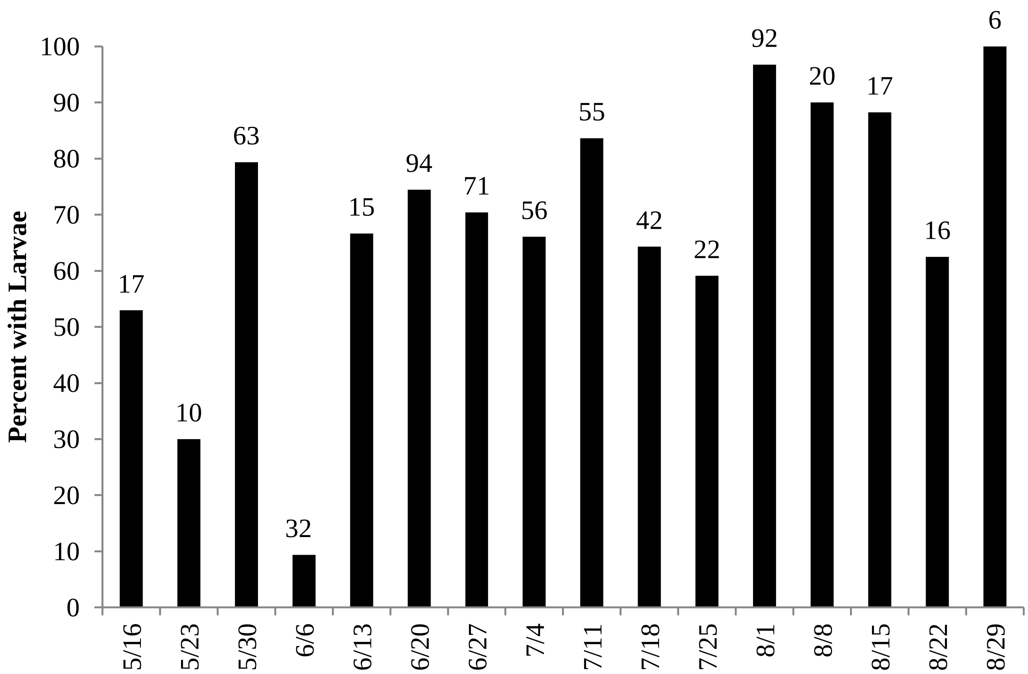


Figure 2.2 Percent of catch basins inspected with mosquitoes present in 2016. Bars are labeled with the number of inspections occurring during the week.

Mosquito larvae were identified from 456 catch basin samples. *Culex restuans* were found in 84.6% of catch basin larval samples (Figure 2.3). *Culex pipiens* were found in 60.3% of samples. At least one *Culex* vector species was found in 98.7% of samples. *Culex restuans* were common in catch basins throughout the season. *Culex pipiens* appeared regularly in catch basins by the week of June 20 and were identified in most samples for the remainder of the season.

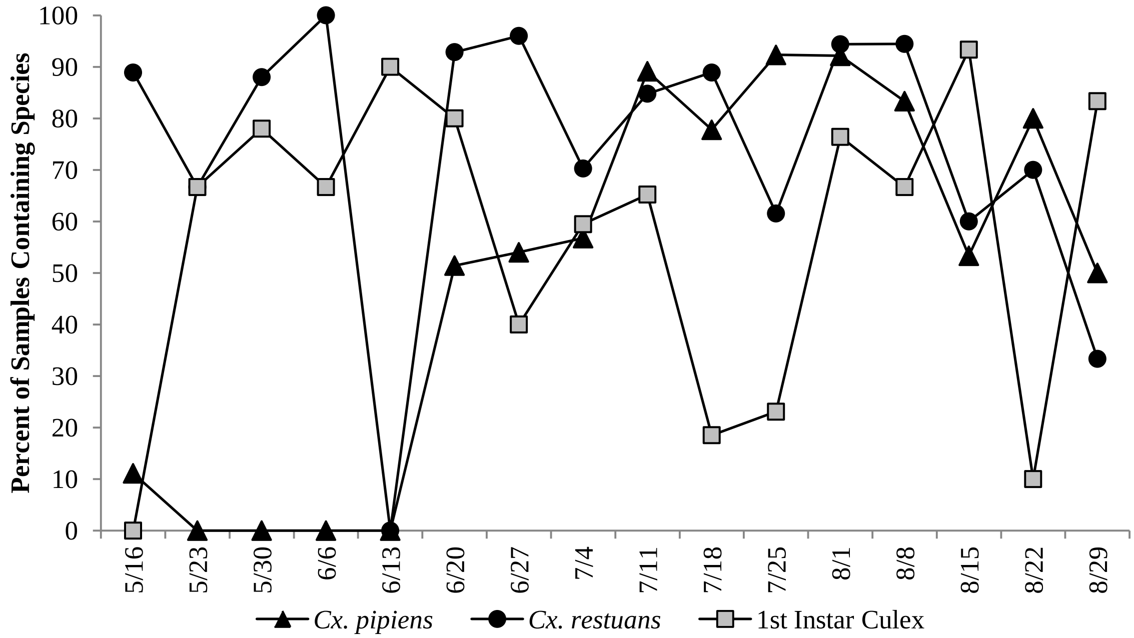


Figure 2.3 Occurrence of *Cx. pipiens* and *Cx. restuans* in catch basin larval samples by week.

2017 Plans – Mosquito-borne Disease

District staff will continue to provide mosquito surveillance and control services for the prevention of La Crosse encephalitis. Preventive measures include *Ae. triseriatus* adult sampling, adult control and, especially, tree hole and container habitat reduction. Eliminating small aquatic habitats will also serve to control populations of *Ae. japonicus*.

The District will continue to survey aquatic habitats for *Culex* larvae for use in design and improvement of larval control strategies. The WNV and WEE vector *Cx. tarsalis* will remain a species of particular interest. Cooperative work with municipalities within the District to treat underground stormwater structures that produce mosquitoes will continue. District staff will continue to target *Culex* larvae in catch basins in our efforts to reduce WNV amplification.

MMCD will continue to conduct surveillance for LAC, WNV, JC, and EEE vectors and for other mosquito-borne viruses in coordination with MDH and others involved in mosquito-borne disease in Minnesota. We plan to work with other agencies, academia, and individuals to improve vector-borne disease prevention in the District, as well as to serve as a resource for others in the state.

Recently, the CDC awarded a grant to the University of Wisconsin to form the Upper Midwestern Center of Excellence in Vector Borne Diseases. The center will draw upon the expertise of a consortium of academic, public health and vector control experts to improve the ability to respond to existing and emerging vector-borne disease threats. MMCD has offered its support to assist the center in meeting its goals.

2016 Tick-borne Disease Services

Background

Infected deer ticks (*Ixodes scapularis*), also known as black-legged ticks, primarily transmit two important diseases in our area. Lyme disease, a bacterial infection caused by the bacterium *Borrelia burgdorferi*, can most notably affect the joints, nervous system, and heart. Human anaplasmosis (HA) is caused by the bacterium *Anaplasma phagocytophilum*. Other rare diseases transmitted by deer ticks include babesiosis and Powassan virus. The Metropolitan Mosquito Control District's Lyme Disease Program identifies and monitors the distribution of deer ticks within the seven-county Twin Cities metropolitan area, ranks the deer tick activity throughout the season, and provides education in preventing tick-borne illness for District residents.

Lyme Disease and Human Anaplasmosis

Our tick surveillance began to detect increases in the metro *I. scapularis* population in 1998, with obvious expansion beginning in 2000. Since then we continue to document record-setting collection seasons on an ongoing basis. In parallel, but with a two year lag (since 2000), the Minnesota Department of Health (MDH) has been documenting ongoing record-setting human tick-borne disease case totals. Pre-2000, the highest Lyme case total was 302 but since 2000 the Lyme totals have ranged from 463 to 1,431 cases, and now typically average >1,000 per year. Human anaplasmosis cases have also been on the rise. After averaging roughly 15 cases per year through 1999, the total HA case numbers ranged from 78 to 186 from 2000 – 2006 then increased into the range of the 300s. The all-time high, statewide Lyme disease case record (1,431) was set in 2013 with the all time high HA record of 782 set in 2011. There were 1,176 Lyme and 613 HA cases in 2015. Case totals from 2016 are not yet available.

Ixodes scapularis Distribution

The District continued to sample the network of 100 sites set up in 1991-1992 to monitor potential changes in tick distribution over time. As in previous years, the primary sampling method involved capturing small mammals from each site and removing any attached ticks from them. Collections from the northeastern metropolitan area (primarily Anoka and Washington counties) have consistently detected *I. scapularis* since 1990, and in 1998 *I. scapularis* was detected in Hennepin and Scott counties for the first time. We collected at least one *I. scapularis* from all seven counties that comprise our service area for the first time in 2007. Since then we have continued to detect *I. scapularis* with greater frequency and they appear to be prevalent now in many wooded areas south of the Mississippi River. The 2016 Lyme Tick Distribution Study report will be available on our website in June (www.mmcd.org/resources/technical-reports). Following are some 2016 highlights.

The average number of *I. scapularis* collected per mammal (1.679) in 2016 is a new record high and surpasses the previous high of 1.450 that had just been set in 2015. However, it is comparable to the averages we have come to expect in recent years (as shown in Table 2.6: 2000 – 2002, 2004, 2005, 2007, 2009, 2010, 2012, 2014, 2015 and 2016 were all ≥ .806).

While it has been typical to tabulate a yearly positive site total in the 50s since 2000, our overall positive site total of 82 for 2016 was a new record high, surpassing the total of 81 that had just been set in 2015 - the first time we had tabulated a site total of 80 or more. In 2014 we had tabulated 75 sites, and the 70 sites we had tabulated for 2010 was the first time of a site total of 70 or more. As has occurred in all years since 2007 except 2011, we collected at least one *I. scapularis* from all seven counties. *Ixodes scapularis* was collected at 53 sites located north of the Mississippi River (Anoka, Washington, and Ramsey counties), and at 29 sites south of the Mississippi River (Dakota, Hennepin, Scott, and Carver counties). Maps are included in our yearly Lyme tick distribution study.

Table 2.6 Yearly totals of the number of mammals trapped and ticks collected (by tick species and life stage), and the average number of *I. scapularis* per mammal, 1990-2016. The number of sites sampled was 250 in 1990, 270 in 1991, 200 in 1992, and 100 from 1993 to present.

			Dermacentor variabilis		*Ixodes scapularis*			
Year	No. mammals	Total ticks collected	No. larvae	No. nymphs	No. larvae	No. nymphs	No. other species[b]	Ave. *I. scap* / mammal
1990 [a]	3651	9957	8289	994	573	74	27	0.177
1991	5566	8452	6807	1094	441	73	37	0.092
1992	2544	4130	3259	703	114	34	20	0.058
1993	1543	1785	1136	221	388	21	19	0.265
1994	1672	1514	797	163	476	67	11	0.325
1995	1406	1196	650	232	258	48	8	0.218
1996	791	724	466	146	82	20	10	0.129
1997	728	693	506	66	96	22	3	0.162
1998	1246	1389	779	100	439	67	4	0.406
1999	1627	1594	820	128	570	64	12	0.390
2000	1173	2207	1030	228	688	257	4	0.806
2001	897	1957	1054	159	697	44	3	0.826
2002	1236	2185	797	280	922	177	9	0.889
2003	1226	1293	676	139	337	140	1	0.377
2004	1152	1773	653	136	901	75	8	0.847
2005	965	1974	708	120	1054	85	7	1.180
2006	1241	1353	411	140	733	58	11	0.591
2007	849	1700	807	136	566	178	13	0.876
2008	702	1005	485	61	340	112	7	0.644
2009	941	1897	916	170	747	61	3	0.859
2010	1320	1553	330	101	1009	107	6	0.845
2011	756	938	373	97	261	205	2	0.616
2012	1537	2223	547	211	1321	139	5	0.950
2013	596	370	88	42	147	92	1	0.401
2014	1396	2427	580	149	1620	74	4	1.213
2015	1195	2217	390	91	1442	291	3	1.450
2016	1374	3038	576	153	2055	252	2	1.679

[a] 1990 data excludes one *Tamias striatus* with 102 *I. scapularis* larvae and 31 nymphs
[b] other species mostly *Ixodes muris.* 1999—second adult *I. muris* collected

Additional Updates – 2016

Posting Signs, Dog Parks Since the initial suggestion of the Technical Advisory Board (TAB) in 2010, we have visited dog parks and vet offices as part of our outreach. Signs have been posted in approximately 21 parks with additional signs posted in active dog walking areas, including at Stubbs Bay Park, Luce Line Trail Entrance. We have also worked on expanding placements into additional metro locations.

Distributing Materials to Targeted Areas Brochures, tick cards, and/or posters were dropped off at roughly 270 locations (city halls, libraries, schools, child care centers, retail establishments, vet clinics, parks) across the metro as well as distributed at fair booths and city events, with many more mailed upon request.

***Amblyomma americanum* (Lone Star Tick) Found in the Metro** *Amblyomma americanum* is an aggressive human biter and can transmit human monocytic ehrlichiosis (HME), among other potential pathogens. Both the tick and HME are more common to the southern US, but the range of *A. americanum* is known to be moving northward. *Amblyomma* ticks have been submitted to MMCD from the public on a rare, sporadic basis and this species was first collected by MMCD in 1991 via a road kill examination of a white-tailed deer (*Odocoileus virginianus*). However, in 2009, for the first time in a number of years, the public submitted *Amblyomma* to both the MDH and MMCD (Minneapolis and Circle Pines). This trend continued in 2010 with *Amblyomma* submitted to MMCD from Eagan, Mound, and the Orono/Lake Minnetonka areas of the metro. In 2011 the MDH had submissions of adults from Shakopee, Lindstrom, and an unconfirmed location in Hennepin County. In 2012, three more *Amblyomma* were submitted to the MDH: Eden Prairie or Burnsville, Bloomington, and Rice County. MMCD did not receive any *Amblyomma* in 2011 or 2012. In 2013, the MDH did not receive any reports but MMCD received three *Amblyomma* (Afton, Scandia, and western Wisconsin). We notified the Wisconsin Department of Health and mailed the western Wisconsin tick to them. In 2014, MMCD did not receive any reports but the MDH received one report from the Zumbrota, MN area. In 2015, MMCD received one adult male and one nymph from the Elk River area, and one additional adult female (unknown location) was collected by a dog groomer in collaboration with the Jordan facility. In 2016 the MMCD did not receive any reports but the MDH received one report from Wabasha County and another from Dakota County.

Tick Identification Services/Outreach

The overall scope of tick-borne disease education activities and services were maintained in 2016 using methods and tools described in previous TAB reports, including weekly updates to our Tick Risk Meter on our website and via MMCD's Facebook page.

2017 Plans for Tick-borne Services

Metro Surveillance

The metro-based *I. scapularis* distribution study that began in 1990 is planned to continue unchanged.

Tick Identification Services/Outreach

Education / Social Media We plan to maintain our tick-borne disease education activities and services (including tick identifications and homeowner consultations) using previously described methods and tools, including weekly website updates of our Tick Risk Meter and occasional use of social media. Since our *I. scapularis* collections and the MDH's human tick-borne disease case totals remain elevated, we will continue to stock local parks and other locations with tick cards, brochures and/or posters and signs. We will also distribute materials at local fairs and the Minnesota State Fair, set up information booths at events as opportunities arise, and continue to offer an encompassing slide presentation.

Signs We will continue to post at dog parks and other appropriate locations. As in past years, signs will be posted in the spring and removed in late fall after *I. scapularis* activity ceases for the year.

***Amblyomma americanum* / New or Unusual Tick Species** MMCD and MDH continue to discuss possible strategies that would enable both agencies to detect possible establishment of *A. americanum* in Minnesota. MMCD will continue to monitor for this tick in our surveillance and to track collections turned in by the public as part of our tick identification service. Both MMCD and MDH plan to maintain our current notification process of contacting the other agency upon identifying an *A. americanum* or other new or unusual tick species.

Additional Projects

Collaborative Study: Testing Nymphal Deer Ticks (ongoing) In 2015 MMCD had provided *I. scapularis* nymphs to PhD student Steve Bennett (UM-St Paul) to be tested for exposure to several tick-borne disease agents. Nymphs from 1990 through 2014 are being tested and any changes over time will be documented.

Chapter 3 Mosquito Control

2016 Highlights

- Larvicide treatments in 2016 (305,972 acres) were lower than the record set in 2015 (326,571 acres)
- A cumulative total of 241,254 catch basin treatments were made in three rounds to control vectors of WNV
- Adulticide treatments in 2016 (82,583 acres) were higher than in 2015 (67,028 acres)

2017 Plans

- Test MetaLarv™ S-PT to control spring *Aedes* as a prehatch
- Maintain September VectoLex® CG treatments as part of our cattail mosquito control program
- Review tests of Natular ™ G to determine reason for inconsistent control of *Cq. perturbans*
- Work closely with MPCA to fulfill the requirements of a NPDES permit
- Continue tests of Onslaught® and other alternate barrier adulticides; specifically target vector mosquitoes
- Continue to increase vector surveillance and control in response to the observed geographic expansion of *Ae. japonicus* within the District

Background

The mosquito control program targets the principal summer pest mosquito *Aedes vexans*, several species of spring *Aedes*, the cattail mosquito *Cq. perturbans*, and several known disease vectors (*Ae. triseriatus, Culex tarsalis, Cx. pipiens, Cx. restuans, Cx. salinarius*) and *Aedes japonicus*, another potential vector species.

Due to the large size of the metropolitan region (2,975 square miles), larval control was considered the most cost-effective control strategy in 1958 and remains so today. Consequently, larval control is the focus of the control program and the most prolific mosquito habitats (over 79,000 potential sites) are scrutinized for all human-biting mosquitoes.

Larval habitats are diverse. They vary from very small, temporary pools that fill after a rainfall to large wetland acreages. Small sites (ground sites) are three acres or less, which field crews treat by hand if larvae are present. Large sites (air sites) are treated by helicopter only after certain criteria are met: larvae occur in sufficient numbers (threshold), larvae are of a certain age (instar), and larvae are the target species (human biting or disease vector).

The insect growth regulator methoprene and the soil bacterium *Bacillus thuringiensis* var *israelensis* or *Bti*, are the primary larval control materials. These active ingredients are used in the trade-named materials Altosid® and MetaLarv™ (methoprene) and VectoBac® (*Bti*). Other materials included in the larval control program are *B. sphaericus* (VectoLex® CG) and Saccharopolyspora spinosa or “spinosad” (Natular™ G30).

To supplement the larval control program, adulticide applications are performed after sampling detects mosquito populations meeting threshold levels, primarily in high use park and recreation areas, for public events, or in response to citizen mosquito annoyance reports. Special emphasis is placed on areas where disease vectors have been detected, especially if there is also evidence of virus circulation.

Four synthetic pyrethroids are used: resmethrin, permethrin, sumithrin and etofenprox. Sumithrin (Anvil®) and two formulations of natural pyrethrins, Pyrenone® and Pyrocide®, can be used in agricultural areas. A description of the control materials is found in Appendix C. Appendix D indicates the dosages of control materials used by MMCD, both in terms of amount of formulated (and in some cases diluted) product applied per acre and the amount of active ingredient (AI) applied per acre. Appendix E contains a historical summary of the number of acres treated with each control material (2008-2016). Pesticide labels are located in Appendix F.

The District uses priority zones to focus service in areas where the highest numbers of citizens benefit (Figure 3.1). Priority zone 1 (P1) contains the majority of the population of the Twin Cities metropolitan area and has boundaries similar to the Metropolitan Urban Service Area (MUSA, Metropolitan Council). Priority zone 2 (P2) includes sparsely populated and rural parts of the District. We consider small towns or population centers in rural areas as satellite communities and they receive services similar to P1. Citizens in P1 receive full larval and adult vector and nuisance mosquito control. In P2, the District focuses on vector control and provides additional larval and adult control services as appropriate and as resources allow.

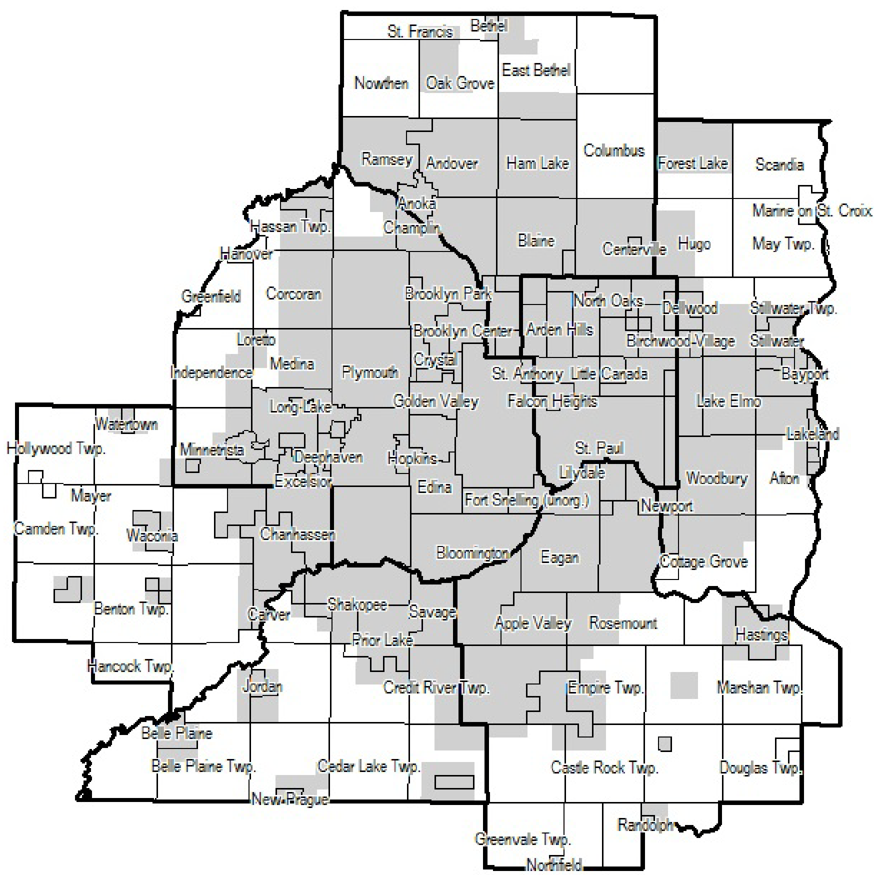


Figure 3.1 Priority zones 1 (shaded) and 2 (white), with District county and city/township boundaries, 2016.

2016 Mosquito Control

Larval Mosquito Control

Thresholds *Bti* treatments in large sites treated by helicopter (i.e., "air sites") are only done when larval numbers meet treatment thresholds, as measured by taking 10 dips with a standard 4-inch diameter dipper. P1 and P2 areas have different thresholds to help focus limited time and materials on productive sites near human population centers (Table 3.1). Spring *Aedes*, which tend to be long-lived, aggressive biters, have lower thresholds. After mid-May, when most larvae found are summer floodwater species, thresholds are increased. If *Aedes* and *Culex* are both present in a site and neither meet threshold, the site can be treated if the combined count meets the threshold.

Table 3.1 Larval thresholds (average number of larvae per ten dips) in priority zone (P1 and P2) by species group

	Priority zone	
Species group	P1	P2
Spring *Aedes*	0.5	1.0
Summer*	2.0	5.0
*Culex*4**	2.0	2.0

*Summer = Summer *Aedes* or *Aedes* + *Culex* 4
**Culex* 4 = *Cx. restuans, Cx. pipiens, Cx. salinarius, Cx. tarsalis*

Season Overview Staff detected the first spring *Aedes* larvae on March 11, nineteen days earlier than in 2015. Aerial *Bti* treatments to control spring *Aedes* began on April 25, three days earlier than in 2015 (see Chapter 6, Fig.6.1 for graphic showing onset of MMCD aerial treatments). The mosquito species composition switched to *Aedes vexans* (summer floodwater) on May 8; after that time the summer threshold was used.

Treatments with materials formulated for application prior to flooding and egg hatch ("prehatch materials") are applied to sites with a history of larvae present. The first "prehatch" treatments were applied in mid-May with a second in mid-June. Methoprene larvicides (MetaLarv S-PT, Altosid pellets) were applied in late May and very early June to control the cattail mosquito.

Precipitation was average in April, lower through June, and much higher in July through September (August especially). We lowered our aerial *Bti* dosage from 8 to 5 lb/acre to conserve remaining control materials on May 16, 2016. By the end of June 2016, we had applied about 91,000 acres worth of *Bti* (Figure 3.2), similar to the 95,000 acres worth applied by the end of June 2015. On July 13, 2016 we increased our aerial *Bti* dosage from 5 to 8 lb/acre to compensate for heavier foliage growth in treatment sites and because the 2016 season seemed to be proceeding more like an average treatment year. In July 2016 we applied 51,000 acres worth of *Bti*, much lower than the 117,000 acres of *Bti* applied in July 2015. On August 12, 2016 we again lowered our aerial *Bti* dosage from 8 to 5 lb/acre to conserve remaining control materials while maintaining good control (Table 5.1). Significant rainfall in August and September 2016 stimulated enough larval floodwater mosquito development to justify 108,000 acres worth of aerial *Bti* treatments, much more than the 59,000 acres treated in August-September 2015. Cattail site inspections in the late summer identified 6,076 acres of *Cq. perturbans* production. On

September 14-15, 2016 we treated these sites with VectoLex. These late summer treatments will decrease the cattail treatment pressure in late spring 2017 when weather and concurrent floodwater mosquito broods can complicate treatment efforts.

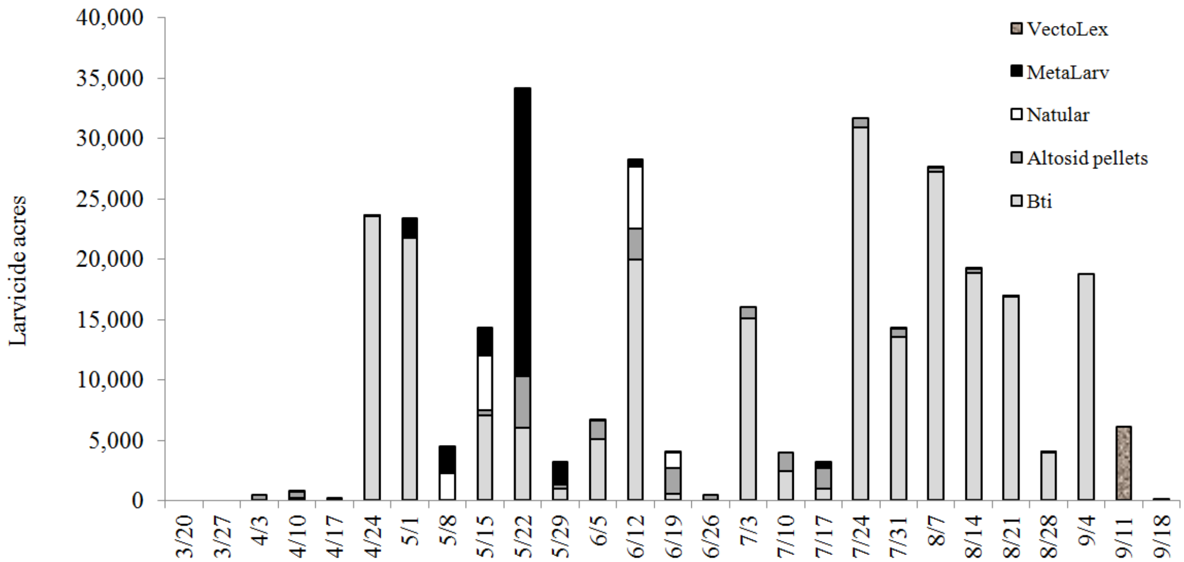


Figure 3.2 Acres treated with larvicide and each week (March-September 2016). Date represents start date of treatment week (Sunday).

While aerial *Bti* treatments began three days earlier in 2016 than in 2015, intense mosquito production again continued throughout the season in 2016 (21 weeks: April 25 through September 10, 2016, compared to 22 weeks: April 28 through September 22, 2015). Treatments targeted one large brood of spring *Aedes* and seven large and eleven small-medium broods of *Ae. vexans* (a typical season has four large broods). Total larval control material use in 2016 was slightly lower than in 2015 (Table 3.2).

Stormwater catch basin treatments to control *Culex* mosquitoes began in early June and ended in early September. Most catch basins were treated three times with Altosid pellets (3.5 grams per catch basin) from June through mid-September (Table 3.2).

We continued to work with Minnesota Pollution Control Agency (MPCA) to satisfy the requirements of our National Pollution Discharge Elimination System (NPDES) permit. We submitted our 2015 treatment report to MPCA in early 2016. Our report contained site-specific larval surveillance and larvicide treatment records and GIS-encoded locations of sites (more details included in Chapter 6). We plan to submit a similar report of 2016 activities in early 2017.

Table 3.2 Comparison of larval control material usage in wetlands (including stormwater structures other than catch basins) and in stormwater catch basins for 2015 and 2016 (research tests not included)

	2015		2016	
Material	Amount used	Area treated	Amount used	Area treated
Wetlands and Structures				
Altosid briquets (cases)	257.63	188 acres	242.37	168 acres
Altosid pellets	108,162.84 lb	31,494 acres	57,529.86 lb	19,173 acres
MetaLarv S-PT	66,488.27 lb	21,126 acres	99,895.94 lb	33,409 acres
Natular G30	51,172.80 lb	8,840 acres	75,197.66 lb	13,023 acres
VectoLex CG	60,039.49 lb	3,777 acres	95,576.64 lb	6,079 acres
VectoBac G	1,827,601.82 lb	258,148 acres	1,629,507.64 lb	234,120 acres
Larvicide subtotals		326,571 acres		305,972 acres
Catch basins				
Altosid briquets (cases)	2.05	450 CB[1]	2.04	448 CB[1]
Altosid pellets	1,933.07 lb	248,599 CB	1,914.63 lb	240,806 CB
CB subtotals		249,049 CB		241,254 CB

[1]CB=catch basin treatments

Adult Mosquito Control

Thresholds Adult mosquito control operations are considered when mosquito levels rise above established thresholds for nuisance (*Aedes* spp. and *Cq. perturbans*) and vector species (Table 3.3). Staff conducted a study in the early 1990s that measured people's perception of annoyance while simultaneously sampling the mosquito population (Read et.al., 1994). Results of this study are the basis of MMCD's nuisance mosquito thresholds. The lower thresholds for vector species are designed to interrupt the vector/virus transmission cycle.

Table 3.3 Thresholds levels by sampling method for important nuisance and vector species detected in MMCD surveillance. *Aedes* spp. and *Cq. perturbans* are considered nuisance mosquitoes; all other species listed are disease vectors

		Total number of mosquitoes			
Species	Date implemented	2-min sweep	CO_2 trap	Aspirator	2-day gravid trap
Aedes triseriatus	1988			2	
Aedes spp. & *Cq. perturbans*	1994	2*	130		
*Culex*4***	2004	1	5	1**	5
Ae. japonicus	2009	1	1	1	1
Cs. melanura	2012		5	5	

*2-minute slap count may be used
**Aspirator threshold only for *Cx. tarsalis*
****Culex*4 = *Cx. restuans, Cx. pipiens, Cx. salinarius, Cx. tarsalis*

Season Overview In 2016, adult mosquito levels rose in mid-June and remained higher through September; at those times, counts over threshold were fairly widespread (Figure 3.3). In 2016, MMCD applied 15,555 more acres worth of adulticides than in 2015 (Table 3.4, Appendix E). Figure 3.3 shows weekly adulticide acres treated (line). The peaks in mid-June through mid-August reflect a response to widespread *Ae. vexans* emergence and increasing numbers of *Culex* (WNV vectors). The proportion of traps over the vector threshold was highest in early August through early September. A greater proportion of ULV and barrier treatments later in the summer targeted vector mosquitoes. Customer calls related to mosquito annoyance were high in June and July (605 and 576, respectively). August had very high call volume – more than June and July combined (1,610). After a peak on August 29, customer calls decreased thereafter (See Chapter 6, Figure 6.2).

Table 3.4 Comparison of adult control material usage in 2015 and 2016

	2015		2016	
Material	Gallons used	Acres treated	Gallons used	Acres treated
Permethrin	1,090.01	6,093	1,405.04	8,128
Resmethrin	239.21	19,767	279.59	23,072
Sumithrin*	645.30	27,183	437.06	16,399
Etofenprox	81.10	10,380	261.66	34,984
Pyrocide*	42.24	3,605	0.00	0
Total		67,028		82,583

* Products labeled for use in agricultural areas

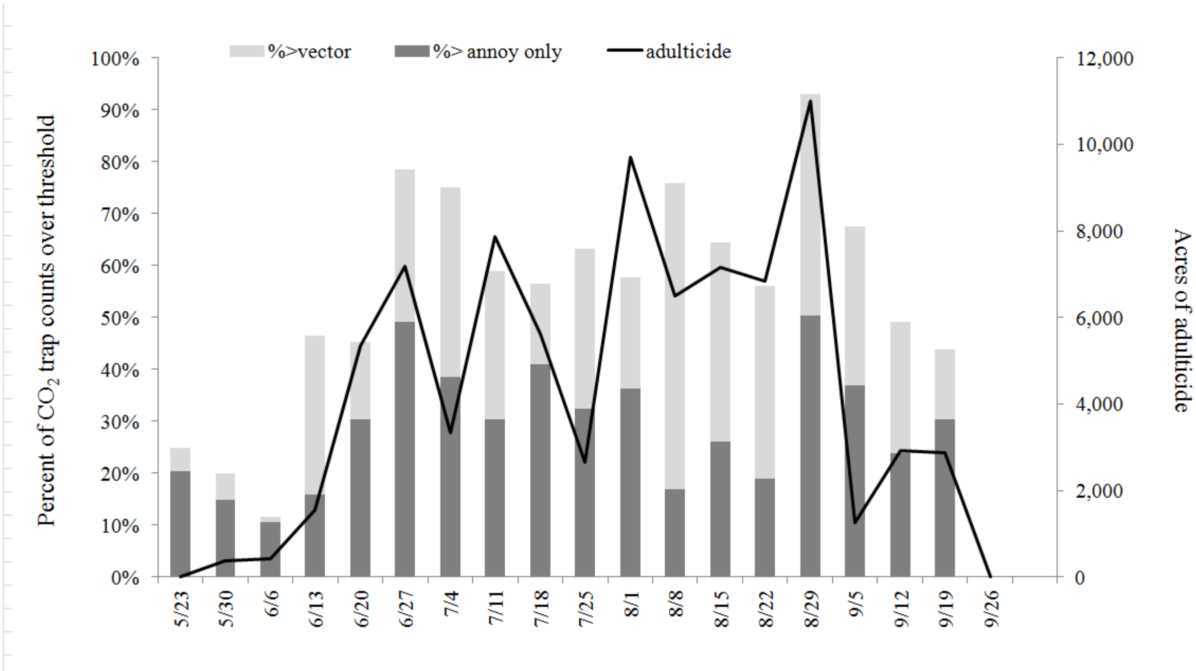


Figure 3.3 Percent of Monday CO_2 trap locations with counts over threshold compared with acres of adulticides applied in 2016 (solid line). Dark bars indicate the percentage of traps meeting annoyance mosquito thresholds and lighter bars represent the percentage of traps meeting the vector thresholds (*Culex*4, *Ae. triseriatus*, *Ae. japonicus*, *Cs. melanura*) on each sampling date. Date is Monday of week.

References

Read, N., J.R. Rooker, and J. Gathman. 1994. Public perception of mosquito annoyance measured by a survey and simultaneous mosquito sampling. J. Am. Mosq. Control Assoc. 10(1): 79-87.

2017 Plans for Mosquito Control Services

Integrated Mosquito Management Program

In 2017, MMCD will review all aspects of its integrated mosquito management program to ensure that budgetary resources are being used as effectively as possible with the goal of maximizing mosquito control services per budget dollar and complying with all NPDES-related permit requirements. Further discussion regarding the Clean Water Act's NPDES permit requirements is in Chapter 6. Our control materials budget in 2017 will be maintained at the same level as 2016.

Larval Control

Cattail Mosquitoes In 2017, control of *Cq. perturbans* will use a strategy similar to that employed in 2017. MMCD will focus control activities on the most productive cattail marshes near human population centers. Altosid briquet applications will start in early March to frozen sites (e.g., floating bogs, deep water cattail sites, remotely located sites). Largely because of control material prices, a greater proportion of acres will be treated with Altosid pellets and MetaLarv S-PT to minimize per-acre treatment costs. Beginning in late May, staff will apply MetaLarv S-PT (3 lb/acre) and Altosid pellets (4 lb/acre) aerially. Ground sites will be treated with Altosid pellets (4 lb/acre) and MetaLarv S-PT (3 lb/acre). Staff will maintain (compared to 2016) late summer VectoLex CG applications (15 lb/acre) into our cattail mosquito control program based upon site inspections completed between mid-August and mid-September.

Floodwater Mosquitoes The primary control material will again be *Bti* corn cob granules. Larvicide needs in 2016, mainly *Bti* (VectoBac G), Altosid pellets, Natular G30, and MetaLarv S-PT, are expected to be similar to the five-year average larvicide usage (281,841 acres). As in previous years, to minimize shortfalls, control material use may be more strictly rationed during the second half of the season, depending upon the amount of the season remaining and control material supplies. Regardless of annoyance levels, MMCD will maintain sufficient resources to protect the public from potential disease risk.

Staff will treat ground sites with methoprene products (Altosid pellets, Altosid briquets, MetaLarv S-PT), Natular G30 or *Bti* corncob granules. During a wide-scale mosquito brood, sites in highly populated areas will receive treatments first. The District will then expand treatments into less populated areas where treatment thresholds are higher. We will continue with the larval treatment thresholds used in 2016 (Table 3.1).

Each year staff review ground site histories to identify those sites that produce mosquitoes most often. This helps us to better prioritize sites to inspect before treatment, sites to pre-treat with

Natular G30 or methoprene products before flooding and egg hatch, and sites not to visit at all. The ultimate aim is to provide larval control services to a larger part of the District by focusing on the most prolific mosquito production sites.

Vector Mosquitoes Employees will routinely monitor and control *Ae. triseriatus*, *Ae. japonicus*, *Ae. albopictus*, *Cs. melanura*, *Cx. tarsalis*, *Cx. pipiens*, *Cx. restuans*, and *Cx. salinarius* populations (See Chapter 2).

MMCD has expanded control to four *Culex* species since the arrival of WNV in 2002. Ground and aerial larvicide treatments of wetlands have been increased to control *Culex*. Catch basin treatments control *Cx. restuans* and *Cx. pipiens* in urban areas. Most catch basins will be treated with Altosid pellets. Catch basins selected for treatment include those found holding water, those that potentially could hold water based on their design, and those for which we have insufficient information to determine whether they will hold water. Treatments could begin as early as the end of May and no later than the third week of June. We tentatively plan to complete a first round of pellet treatments by June 25 with subsequent Altosid pellet treatments every 30 days.

We intend to continue working cooperatively with cities to treat underground stormwater management structures (see Chapter 2) and slowly expand the kinds of structures we treat with larvicides beyond pond level regulators.

Intensive surveillance for *Ae. japonicus* and *Cs. melanura* will continue in 2017 to determine abundance and common larval habitats and refine potential larval control methods.

Adult Mosquito Control

Staff will continue to review MMCD's adulticide program to ensure effective resource use and minimize possible non-target effects. Adulticide requirements in 2017 are expected to be similar to the five-year average adulticide usage (73,302 acres). We will continue to focus efforts where there is potential disease risk, as well as provide service in high-use park and recreation areas and for public functions, and respond to areas where high mosquito numbers are affecting citizens.

Additional plans are:

- to use Anvil (sumithrin) as needed to control WNV vectors in agricultural areas because the updated label now allows applications in these areas;
- to evaluate possible adulticide use in response to *Ae. japonicus* and *Cs. melanura*;
- to replace Scourge (resmethrin), which was phased out in 2016, with Anvil and Zenivex (etofenprox); and
- to ensure all employees who may apply adulticides have passed applicator certification testing for both restricted and non-restricted use products.

Chapter 4 Black Fly Control

2016 Highlights

- Treated 20 small streams sites with *Bti* when the *Simulium venustum* larval population met the treatment threshold; a total of 15.3 gallons of *Bti* was used
- Made 58 *Bti* treatments on the large rivers when the larval population of target species met the treatment threshold; a total of 3,096.2 gallons of *Bti* was used for these treatments
- Monitored adult populations using overhead net sweeps and CO_2 traps; the average black fly/overhead sweep was 0.34, the second lowest number since the black fly program started in 1984

2017 Plans

- Monitor larval black fly populations in small streams and large rivers; apply *Bti* when treatment thresholds are met
- Monitor adult populations by the overhead net sweep and CO_2 trap methods
- Finish processing Mississippi River non-target monitoring samples collected in 2015 and report the results

Background

The goal of the black fly control program is to reduce pest populations of adult black flies within the MMCD to tolerable levels. Black flies develop in clean flowing rivers and streams. Larval populations are monitored at 168 small stream and 28 large river sites using standardized sampling techniques during the spring and summer. Liquid *Bti* is applied to sites when the target species reach treatment thresholds in accordance with MMCD's permit from the Minnesota Department of Natural Resources (MnDNR).

The small stream treatment program began in 1984. The large river program began with experimental treatments and non-target impact studies in 1987. A full-scale large river treatment program did not go into effect until 1996. The large river treatment program was expanded in 2005 to include the South Fork Crow River in Carver County. Large river and small stream monitoring/treatment locations are shown in Figure 4.1.

2016 Program

Small Stream Program: *Simulium venustum* Control

Simulium venustum is the only human-biting black fly species that develops in small streams in the MMCD area that is targeted for control. It has one generation in the spring.

In April, 178 larval monitoring samples were collected from the small streams within the MMCD to determine larval abundance using the standard grab sampling technique developed by the MMCD. The treatment threshold was 100 *S. venustum* per sample. A total of 20 sites on 11 streams met the threshold and were treated once with VectoBac® 12AS *Bti*. A total of 15.3 gallons of VectoBac was used for the treatments (Table 4.1). In comparison, the average amount of *Bti* used to treat the small stream sites annually during 1996-2015 was 28 gallons.

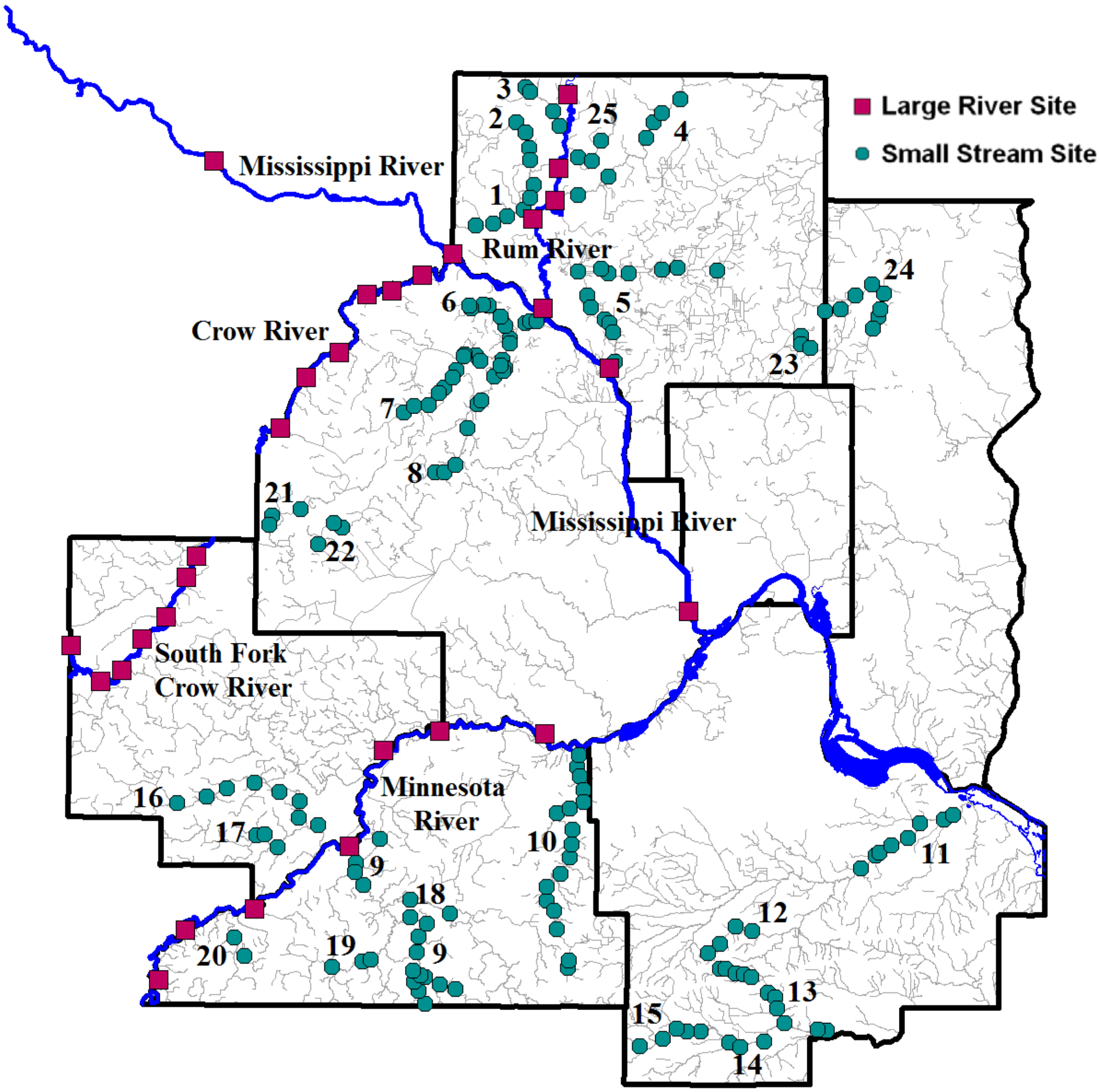


Figure 4.1 Large river and small stream black fly larval monitoring/treatment locations, 2016. Note: the large river site located outside the District on the Mississippi River is for monitoring only. Since 1991 more than 450 of the more than 600 original small stream treatment sites were eliminated from the annual small stream sampling program due to the increased treatment threshold as well as our findings from years of sampling that some sites did not produce any, or very few, *S. venustum.* Periodically historical sites that were eliminated from the permit are sampled to confirm if larval populations are present or absent. Requests are made to add new sites if larval monitoring confirms elevated *S. venustum* populations. The numbers on the map refer to the small stream names listed below:

1=Trott	6=Diamond	11=Vermillion	16=Bevens	21=Pioneer
2=Ford	7=Rush	12=Vermillion So. Branch	17=Silver	22=Painter
3=Seelye	8=Elm	13=Chub No. Branch	18=Porter	23=Clearwater
4=Cedar	9=Sand	14=Chub	19=Raven W. Br.	24=Hardwood
5=Coon	10=Credit	15=Dutch	20=Robert	25=Ditch 19

Table 4.1 Summary of *Bti* treatments for black fly control by the MMCD in 2015 and 2016

	2015			2016		
Water body	No. sites treated	Total no. treatments	Gallons of *Bti* used	No. sites treated	Total no. treatments	Gallons of *Bti* used
Small Stream Totals	48	48	41.2	20	20	15.3
Large River						
Mississippi	2	10	1,070.3	2	2	330.0
Crow	3	13	165.0	3	8	155.0
South Fork Crow	6	14	50.3	7	15	137.5
Minnesota	7	38	2,887.6	7	21	2,364.7
Rum	4	21	136.3	2	12	109.0
Large River Totals	22	96	4,309.5	21	58	3,096.2
Grand Total	70	144	4,350.7	41	78	3,111.5

Large River Program

MMCD targets three large river black fly species for control with *Bti*. *Simulium luggeri* larvae occur mainly in the Rum and Mississippi rivers, although they also occur in smaller numbers in the Minnesota and Crow rivers. Depending on river flow, *S. luggeri* is abundant from mid-May through September. *Simulium meridionale* and *Simulium johannseni* larvae occur primarily in the Crow, South Fork Crow, and Minnesota rivers. These species are most abundant in May and June, although *S. meridionale* populations may remain high throughout the summer if river flow is also high.

The large river black fly larval populations were monitored weekly between late April and mid-September using artificial substrate samplers (Mylar tapes) at the 28 sites permitted by the MnDNR on the Rum, Mississippi, Crow, South Fork Crow, and Minnesota rivers to determine if the treatment threshold was met. The treatment threshold for *S. luggeri* was an average of 100 larvae/sampler at each treatment site location. The treatment threshold for *S. meridionale* and *S. johannseni* was an average of 40 larvae/per sampler at each treatment site location. These were the same treatment thresholds used since 1990.

A total of 479 larval monitoring samples were collected from the 28 permitted sites in 2016. The treatment threshold was met in 58 of these samples at 21 of the permitted sites and the associated sites were treated with a total of 3,096.2 gallons of VectoBac 12AS *Bti* (Table 4.1). In comparison, the average amount of *Bti* used on the large river treatments annually between 1996 and 2015 was 3,140 gallons. The Mississippi River was only treated twice in 2016; the fewest number of treatments done on the Mississippi River since the start of the full operational program in 1996. The average number of annual *Bti* treatments on the Mississippi River between 1996 and 2015 is 11.6 (range: 6 – 22). Flows were below normal on both the Mississippi and Rum rivers in April, May and June and above normal from July through September. In contrast, on the Minnesota, Crow and South Fork Crow rivers flow was below normal in April but much higher than normal for the remainder of the season.

The efficacy of the VectoBac 12AS treatments is measured by determining larval mortality 250 m downstream from the *Bti* application point. In 2016, the average larval mortality of the treatments was 99% on the Minnesota River, 95% on the Rum River, 87% on the Crow River, and 95% on the South Fork Crow River. Post treatment mortality was not determined for the two treatments on the Mississippi River.

Adult Population Sampling

Daytime Sweep Net Collections The adult black fly population was monitored at 53 standard stations (Figure 4.2) using the District's black fly over-head net sweep technique that was established in 1984. Samples were taken once weekly from early May to mid-September, generally between 8:00 A.M. and 10:00 A.M. The average number of all species of adult black flies captured in 2016 was 0.34 (± 1.33 S.D.). In comparison, the average of all species captured in net sweeps from 1996, when operational treatments began, through 2015 was 1.40 (± 0.79) (Table 4.2). Between 1984 and 1986 when no *Bti* treatments were done on the large rivers, the average number of all species of adults captured in the net sweeps was 14.80 (± 3.04 S.D.).

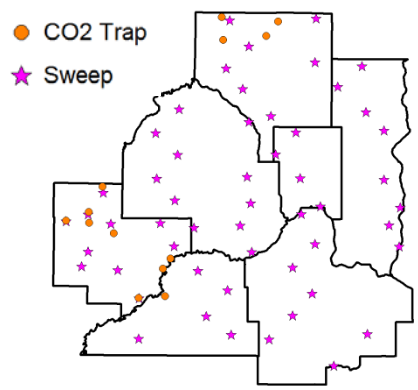


Figure 4.2 Adult black fly sweep and CO_2 trap sampling locations, 2016.

The most abundant black fly collected in the overhead net-sweep samples in 2016 was *S. meridionale*, comprising 51.9% of the total captured with an average of 0.18 per sample. The second most abundant black fly species captured was *S. luggeri*, comprising 34.7% of the total captured with an average of 0.12 per sample.

Among the seven counties of the MMCD, Carver County had the highest average number (0.96) of all black fly species captured in net sweep samples in 2016. *Simulium meridionale* was the most abundant black fly captured in Carver County with an average of 0.79 per sample. The second highest number of all black flies captured per sample was in Anoka County with an average of 0.82 per sample. The most abundant species captured in Anoka County was *S. luggeri* with an average of 0.68 per sample. The high number of *S. meridionale* captured in Carver County is due to the fact that the prime larval habitat for this species is found in the nearby Crow, South Fork Crow, and Minnesota rivers. Likewise, the best larval habitat for *S. luggeri* in the MMCD is located on reaches of the Mississippi and Rum rivers in Anoka County.

Table 4.2 Mean number of black fly adults captured in over-head net sweeps taken at standard sampling locations between mid-May and mid-September; samples were taken once weekly beginning in 2004 and twice weekly in previous years

Large River *Bti* Treatment Status[1,2,3,4]	Time Period	Mean ± S.D.			
		All species[5]	*Simulium luggeri*	*Simulium johannseni*	*Simulium meridionale*
No treatments	1984 to 1986	14.80 ± 3.04	13.11 ± 3.45	0.24 ± 0.39	1.25 ± 0.55
Experimental treatments	1987 to 1995	3.63 ± 2.00	3.16 ± 2.05	0.10 ± 0.12	0.29 ± 0.40
Operational treatments	1996 to 2015	1.40 ± 0.79	1.12 ± 0.76	0.02 ± 0.02	0.15 ± 0.12
	2016	0.34 ± 1.33	0.12 ± 0.73	0.02 ± 0.28	0.18 ± 0.99

[1]1988 was a severe drought year and limited black fly production occurred.
[2]The first operational treatments of the Mississippi River began in 1990 at the Coon Rapids Dam.
[3]1996 was the first year of operational treatments (treatment of all MnDNR-permitted sites) on the large rivers.
[4]Expanded operational treatments began in 2006 when permits where received from the MnDNR for treatments on the So. Fork Crow River.
[5]All species includes *S. luggeri*, *S. meridionale*, *S. johannseni*, and all other species collected.

Black Fly-Specific CO_2 Trap Collections Adult black fly populations were monitored from mid-May to mid-June in 2016 with CO_2 traps at four stations each in Scott and Anoka counties, and five stations in Carver County (Figure 4.2). The adult black population at these stations has been monitored with CO_2 traps since 2004 when larval treatments began on the South Fork Crow River. Black flies captured in these CO_2 traps are preserved in alcohol to facilitate species identification.

A total of 32,370 adult black flies were collected in the CO_2 traps in 2016. This was the largest number of black flies collected in the CO_2 traps since 2011 when 274,925 were collected. *Simulium meridionale* was the most abundant species collected in 2016, comprising 93% of the total black flies captured. 30,097 *S. meridionale* were collected in all the traps, of which 27,100 (84%) were collected in the five Carver County traps. The mean number of *S. meridionale* captured in the Carver Country traps was 501.85 ±1013.79, whereas the mean number captured in the Scott County traps was 64.33 ± 196.28 and 0.86 ± 2.23 in the Anoka County traps. *Simulium johannseni* was the second most abundant species captured in the CO_2 traps in 2016 with a total of 2,111 (6.5%) captured. The largest number of *S. johannseni* was captured in Carver County with an average of 35.41 ± 89.56 per trap; in Scott County the average number captured was of 2.89 ± 8.92 and in Anoka County the average per trap was 1.50 ± 4.63.

Monday Night CO_2 Trap Collections Black flies captured in District-wide weekly CO_2 trap collections (see Chapter 1, Fig. 1.5, pg 7) were counted and identified to family level in

2016. Because these traps are operated for mosquito surveillance, samples are not placed in ethyl alcohol making black fly species-level identification difficult. Results are represented geographically in Figure 4.3. The areas in dark gray and black represent the highest numbers collected, ranging from 250 to more than 500 per trap. The highest number of black flies was observed in May, June, and early July in parts of Carver and Hennepin counties (Figure 4.3).

Non-target Monitoring

The District has conducted biennial monitoring of the non-target macroinvertebrate population in the Mississippi River as part of its MNDNR permit requirements since 1995. The monitoring program was designed as a long-term assessment of the macroinvertebrate community in *Bti*-treated reaches of the Mississippi River. Results from the monitoring studies show that there have been no large-scale changes in the macroinvertebrate community in the *Bti*-treated reaches of the Mississippi River as a result of the black fly control program. Monitoring samples were collected from the Mississippi River in 2015. A report is scheduled for completion in early 2017.

2017 Plans – Black Fly Program

2017 will be the 33rd year of black fly control in the District. The primary goal in 2017 will be to continue to effectively monitor and control black flies in the large rivers and small streams. The larval population monitoring program and thresholds for treatment with *Bti* will continue as in previous years. In addition, field crews will continue to test bulk control material containers as a part of the broader sustainability efforts of the District. The 2017 black fly control permit application will be submitted to the MNDNR in February. A report from the non-target invertebrate monitoring samples collected from the Mississippi River in 2015 will be completed. Program development will continue to emphasize improvement in effectiveness, surveillance, and efficiency.

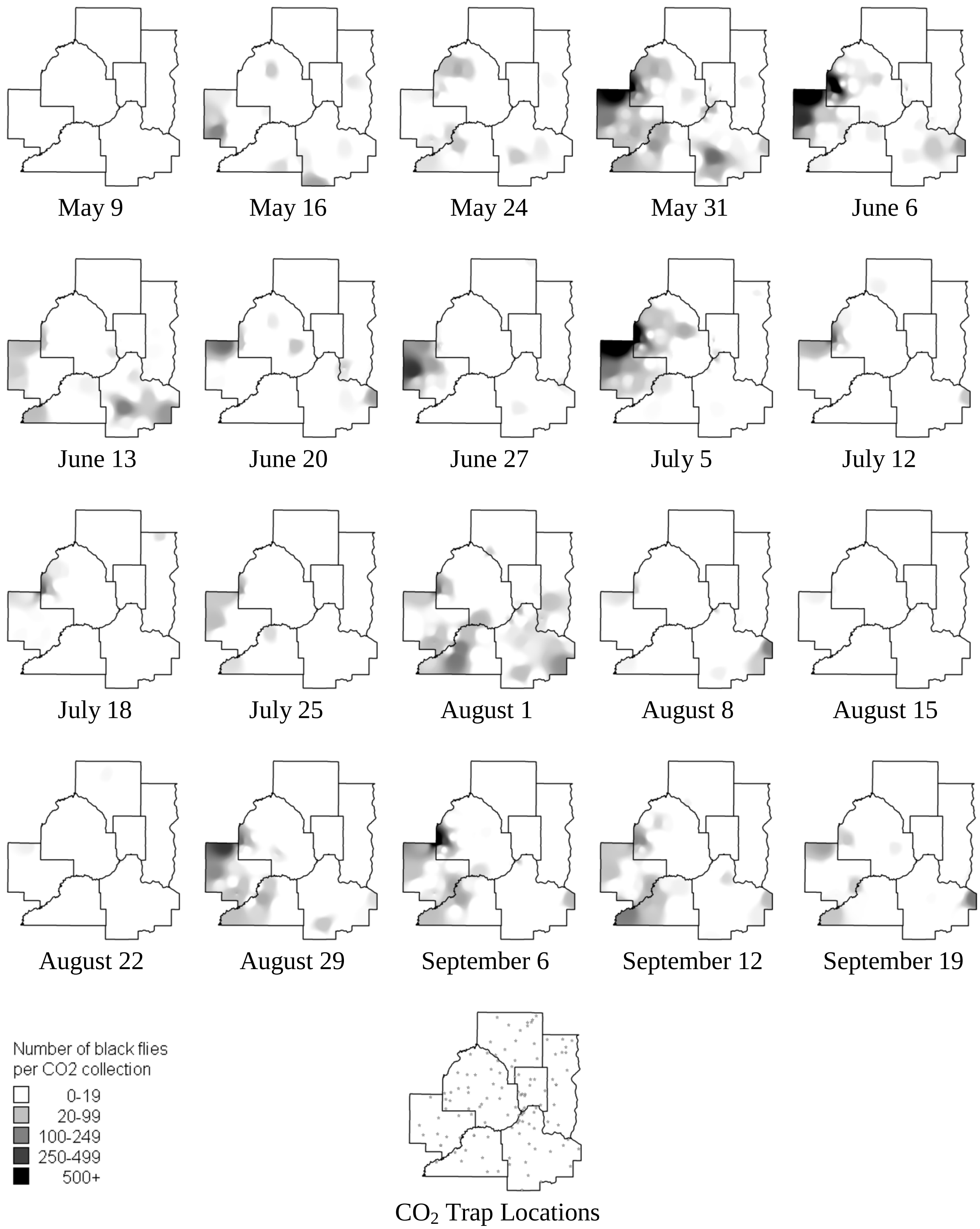


Figure 4.3 Number of black flies collected in mosquito surveillance District low (5 ft) and elevated (25 ft) CO_2 traps, 2016. The number of traps operated per night varied from 109-123. Inverse distance weighting was the algorithm used for shading of maps.

Chapter 5 Product & Equipment Tests

2016 Highlights

- Both 8- and 5-lb/acre dosages of VectoBac® G *Bti* achieved good control of *Ae. vexans* in air sites
- Natular G™ did not control cattail mosquitoes as effectively as desired. Adult emergence was not suppressed two or more weeks after treatment
- Onslaught® (barrier) controlled mosquitoes for at least 24 hours in woodlots when mosquitoes were very abundant before treatment
- Merus® and Anvil® (ULV) both controlled mosquitoes effectively for 24 hours when mosquitoes were very abundant before treatment

2017 Plans

- Maintain late summer cattail treatments of VectoLex® CG to control the cattail mosquito
- Repeat tests of MetaLarv™ S-PT against spring *Aedes* to evaluate its effectiveness as a spring pre-hatch larvicide
- Continue tests of adulticides in different situations emphasizing control of vectors and effectiveness of barrier treatments

Background

Evaluation of current and potential control materials and equipment is essential for MMCD to provide cost-effective service. MMCD regularly evaluates the effectiveness of ongoing operations to verify efficacy. Tests of new materials, methods, and equipment enable MMCD to continuously improve operations.

2016 Projects

Quality assurance processes focused on product evaluations, equipment, and waste reduction. Before being used operationally, all products must complete a certification process that consists of tests to demonstrate how to use the product to effectively control mosquitoes. The District continued certification testing of two larvicides and two new adulticides. The larvicides and adulticides have been tested in different control situations in the past. Our goal is to determine that different larvicides can control two or more target mosquito species (i.e., nuisance or disease vector) in multiple control situations. One adulticide was tested as an alternative ULV (nighttime fogging, Merus) material and the other as an alternative barrier (mosquito harborage treatment, Onslaught) material. These additional control materials provide MMCD with more operational tools.

Control Material Acceptance Testing

Larval Mosquito Control Products Warehouse staff collected random product samples from shipments received from manufacturers for active ingredient (AI) content analysis. MMCD contracts an independent testing laboratory, Legend Technical Services, to complete the AI analysis. Manufacturers provide the testing methodologies. The laboratory protocols used were CAP No. 311, “Procedures for the Analysis of S-Methoprene in Briquets and Premix”, CAP No. 313, “Procedure for the Analysis of S-Methoprene in Sand Formulations”, VBC Analytical Method: VBC-M07-001.1 Analytical Method for the Determination of (S)-Methoprene by High Performance Liquid Chromatography and Clarke Analytical Test Method SP-003 Revision #2

"HPLC Determination of Spinosad Content in Natular G30 Granules."

The manufacturer's certificates of analysis at the time of manufacture for samples of all control materials shipped to MMCD in 2016 were all within acceptable limits. Due to the high expenses of the 2016 mosquito season and the significant cost of independent laboratory evaluation, 2016 product samples have been retained and random samples will be submitted with 2017 samples to lower our overall expenditures.

Adult Mosquito Control Products MMCD requests certificates of AI analysis from the manufacturers to verify product AI levels at the time of manufacture. MMCD has incorporated AI analysis as part of a product evaluation procedure and will submit randomly selected samples of adulticide control materials to an independent laboratory for AI level verification. This process will assure that all adulticides (purchased, formulated, and/or stored) meet the necessary quality standards. In 2016, MMCD sampled but did not analyze adulticide products and saved voucher samples for reference.

Efficacy of Control Materials

VectoBac® G VectoBac G brand *Bti* (5/8 inch mesh size corncob granules) from Valent BioSciences was the primary *Bti* product applied by helicopter in 2016. Aerial *Bti* treatments began April 28 (three days later than in 2015). We applied 8 lb/acre to control spring *Aedes* and switched to the 5 lb/acre rate beginning on May 16 to control *Ae. vexans*. Because of staff concern about effective penetration of foliage in treatment sites we switched to 8 lb/acre on July 6. We switched back to the 5 lb/acre rate on August 12 to conserve budgetary resources because of greatly increased rainfall beginning in mid-July. In 2016 aerial *Bti* treatments achieved an average of 86.0% control (Table 5.1), comparable to 83.7% control in 2015 and 90.4% control in 2014. Effectiveness of both rates was remarkably uniform throughout the 2016 season. Percent mortality was calculated by comparing pre- and post-treatment dip counts.

Table 5.1 Efficacy of aerial VectoBac G applications (8 lb and 5 lb/acre) in different time periods of the 2016 mosquito season

Time period	Dosage rate	n	Mean mortality	±SE*
April 25 – May 5	8 lb/acre	182	86.7%	2.2%
May 16 – June 24	5 lb/acre	320	85.9%	1.6%
July 6 – August 8	8 lb/acre	350	89.0%	1.5%
August 12 – Sept 10	5 lb/acre	277	82.1%	1.9%
April 25 – Sept 10	All rates	1,129	86.0%	0.9%

*SE= standard error

New Control Material Evaluations

The District, as part of its Continuous Quality Improvement philosophy, strives to continually improve its control methods. Testing in 2016 was designed to evaluate how different segments of mosquito control programs can be modified to deliver more mosquito control services to a greater part of the District area using existing resources. Much testing has focused upon controlling multiple mosquito species including potential vectors of WNV.

Larval Control

Largely because of low water levels in April through June, we were unable to complete robust tests of larvicides containing methoprene such as Valent MetaLarv™ S-PT to control spring *Aedes*. We did manage to collect two bioassays from sites treated with MetaLarv S-PT (2.5 lb/acre). Both bioassays yielded good results (100% and 83% inhibition of adult mosquito emergence) suggesting that MetaLarv S-PT can effectively control spring *Aedes*. We were unable to correct the treated bioassay results for control mortality because no pupae were found in untreated sites. However, these two bioassay results both suggested significant control compared to control mortality observed in the past. Control mortality results from tests in spring *Aedes* sites completed in 2013 averaged 8.9% inhibition of adult mosquito emergence (n=11, 95% confidence limits: 2.1% to 24.3%) (see 2013 Operational Review and Plans for 2014 for details). We need to repeat these tests in 2017.

***Coquillettidia perturbans* Control** *Coquillettidia perturbans* is an abundant pest that lays its eggs in mid- to late summer and overwinters as larvae attached to aquatic vegetation, primarily cattail roots. Our current control strategy includes large-scale ground and aerial treatments for this single brood mosquito in late May, just prior to its emergence. See Chapter 1, pages 12 and 14 for geographic and temporal patterns of *Cq. emergence* in 2016. We have tested larvicides containing biorational actives (e.g., VectoLex CG, Natular G30, Natular G) other than methoprene to determine which others we might be able to add to our control program.

Clarke Natular G-Early June Treatments In 2012, we completed a very small test of the spinosad formulation Natular G30 (10 lb/acre) to control *Cq. perturbans*. Results were disappointing (62% control) but the sample size was very small and mosquito emergence in the untreated control was low (see 2012 Operational Review and Plans for 2013 for details). Results of a repeat test in 2014 were more promising (see 2014 Operational Review and Plans for 2015 for details). We chose to test Natular G in 2015 because the per-acre cost is much lower than the same rate (5 lb/acre) of Natular G30. Results of a test of Natular G in 2015 again were disappointing (25% control) (see 2015 Operational Review and Plans for 2016 for details).

We tested Natular G again in 2016 to try to determine the reasons for inconsistent results. In 2016, we selected ten ground cattail sites with a history of high *Cq. perturbans* emergence. Five sites were in Greenfield in Hennepin County (untreated) and five sites were in Forest Lake and Hugo, Washington County (treated with Natular G). On June 2, 2016 sites were treated with Natular G (5 lb/acre treatment rate). Immediately after treatment, five emergence cages were placed in each of these 10 sites on June 2, 2016. All adult mosquitoes captured by emergence cages were removed twice each week beginning on June 6 and ending on July 28. Data were analyzed after sampling ended.

Emergence of adult *Cq. perturbans* (in terms of mean adult emergence per cage) from sites treated with Natular G was much higher early in the sampling period (5.1 per cage, SE=2.23) than emergence from untreated sites (3.6 per cage, SE=1.66) (Figure 5.1). However, adult emergence eleven or more days after treatment with Natular G was lower (3.6 per cage, SE=1.66) than emergence from untreated sites during the same period (5.1 per cage, SE=2.23) (Figure 5.2) perhaps suggesting that either most adults emerged earlier in the Natular G treated sites or that spinosad, the active ingredient in Natular G, needed time to reach and control *Cq. perturbans* developing in treated sites.

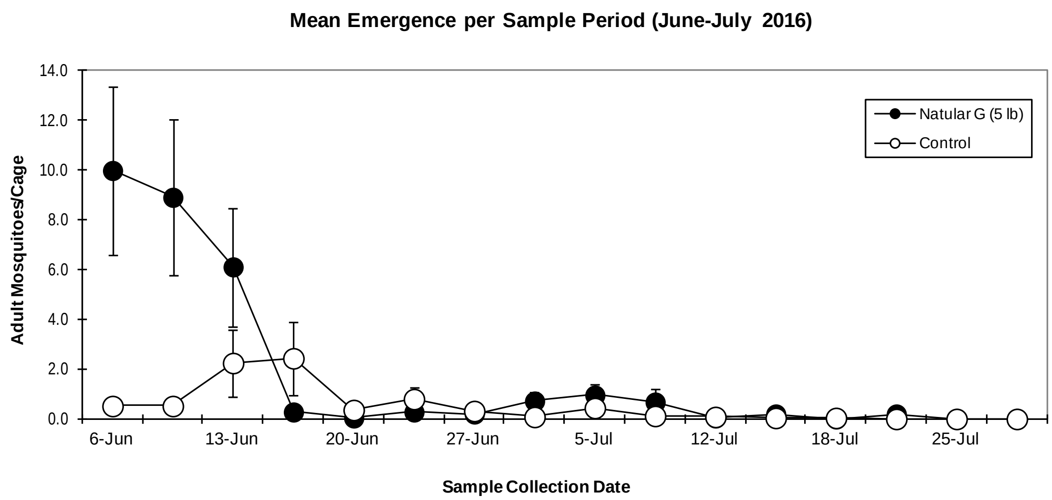


Figure 5.1 Mean emergence (±SE) of *Cq. perturbans* per sample period in cages in sites treated with Natular G and untreated sites June 6 – July 28, 2016.

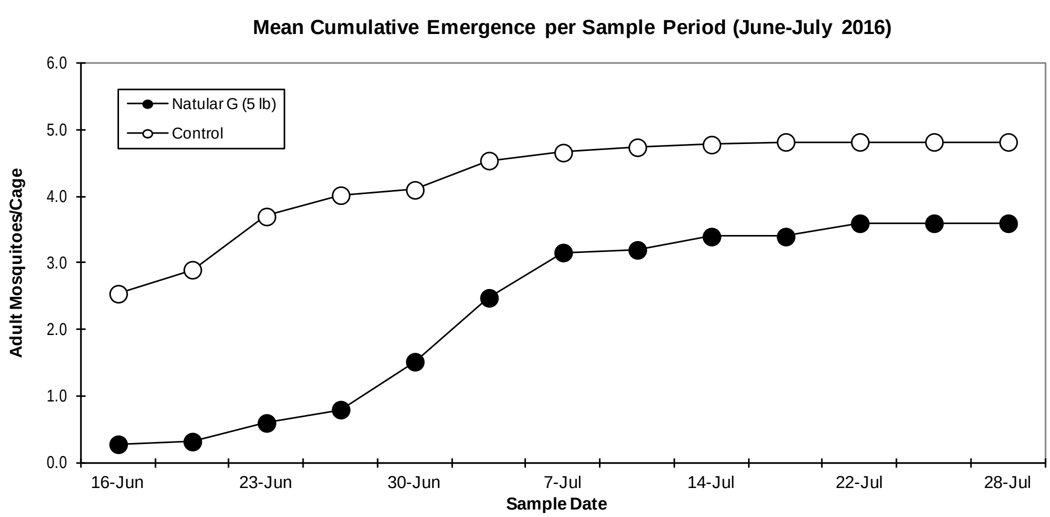


Figure 5.2 Mean cumulative emergence of *Cq. perturbans* in cages in sites treated with Natular G and untreated sites, June 16 – July 28, 2016.

The percentage of cages in which *Cq. perturbans* emerged between June 13 – July 28, 2016 was not significantly different in Natular G treated sites compared to untreated sites (Table 5.2). We thought control might be better if Natular G was applied sooner before emergence. We now believe inconsistent delivery of the active (spinosad) to larvae on cattail roots, perhaps due to formulation or material dosage, more likely is the cause of inconsistent results. We need to review more information about how the active spinosad moves through water in cattail marshes before considering additional tests.

Table 5.2 Emergence of *Cq. perturbans* in sites treated with blank granules or Natular G, June 13 – July 28, 2016

Treatment	Total cages	No. positive cages	% positive cages	MCE§	% control	Fisher Exact p-value*
Untreated Control	23	13	56.5	4.82	N/A	N/A
Natular G	25	12	48.0	3.60	25.3	0.192

§MCE, mean cumulative emergence per cage
*Untreated control compared to Natular G

Adulticide Tests

Beginning in 2008, research focused upon evaluating how effectively barrier and ULV (cold fogging) treatments controlled mosquitoes, especially West Nile virus vectors. This research is partially in response to recommendations by the Technical Advisory Board that MMCD demonstrate vector-specific efficacy, especially for barrier permethrin treatments that pose the greatest potential risk to non-target organisms in treated areas.

Permethrin and Onslaught® Barrier As in previous years, tests of Onslaught® FastCap (synthetic pyrethroid esfenvalerate plus synergists) were conducted in woodlots where operational permethrin treatments could potentially be made and all tests included untreated woodlots. All tests included CO_2 trap data. CO_2 traps (two of each per woodlot) were placed 24 hours before treatment, 30 minutes after treatment, 24 hours after treatment, and one week after treatment. Efficacy was evaluated using Mulla's equation (a correction that accounts for natural changes in the untreated control site, as well as the treatment site). The goal of all tests was to better evaluate the duration and consistency of control achieved by barrier treatments and to include vector-specific efficacy evaluations.

One test was completed August 3-5, 2016 in a pair of woodlots in Hennepin County (Linner Park in Minnetonka) that had a history of high adult mosquito abundance. Storms one week after treatment precluded collection of 7-day post treatment samples. Onslaught achieved significant control of all mosquitoes within 24 hours of treatment (Table 5.3). Control declined thereafter but was still detectable (44.5%) one day after treatment (Table 5.3). Adult mosquito abundance was high meaning this was a tougher test of Onslaught because only small areas are treated with many mosquitoes quickly moving into the treated areas from surrounding areas. None of the CO_2 traps captured enough *Culex* vectors, *Ae. triseriatus*, or *Ae. japonicus* to evaluate effectiveness against disease vectors.

Table 5.3 Barrier Onslaught treatment efficacy: (8/3 – 8/5): Efficacy percent calculated using Mulla's formula*

Test 1	Collection	All mosquito species CO_2 trap catch§		All mosquito species Efficacy*
Onslaught	Pre-treat	342.0	(±90.0)	---
	Post-treat	349.5	(±97.5)	74.2%
	Post-24 h	141.0	(±3.0)	44.8%
Untreated control	Pre-treat	278.0	(±123.0)	---
	Post-treat	1,110.0	(±508.0)	---
	Post-24 h	207.5	(±44.5)	---

*Mulla's formula incorporates untreated control trap counts to correct for changes in the treated traps that are not due to the treatment

§Mean (±SE), n=2 (CO_2 traps)

Between 2006 and 2013, we completed 18 barrier tests that included permethrin. Permethrin effectively controlled adult mosquitoes within 24 hours after treatment in most tests (Table 5.4). Permethrin also effectively controlled vector mosquitoes within 24 hours after treatment in most tests where enough vectors were captured to evaluate efficacy. One week after treatment permethrin effectively controlled adult mosquitoes in only about half of those tests (Table 5.4). See 2006, 2007, 2008, 2010 and 2011 Operational Reviews for details.

We completed eleven barrier tests that included Onslaught between 2007 and 2016. The proportion of tests in which Onslaught was able to effectively control adult mosquitoes was similar to permethrin. Onslaught is able to control *Culex* vectors within 24 hours after treatment with control persisting up to one week. Insufficient data are available to evaluate effectiveness against *Ae. triseriatus* (Table 5.4) (see 2006, 2007, 2008, 2010, 2011, 2012, 2014 and 2015 Operational Reviews for details).

Table 5.4 Permethrin and Onslaught barrier tests with high efficacy (>80% control using Mulla's equation). Tests occurred from 2006-2013 for permethrin and 2007-2015 for Onslaught

Material used and number of tests*	Target mosquitoes	No. tests with high efficacy (% tests with high efficacy): 24-48 hours after treatment	No. tests with high efficacy (% tests with high efficacy): 7 days after treatment
Permethrin (2006-2013)			
18	All species	16 (89%)	7 (39%)
9	*Culex* (WNV) **	7 (78%)	4 (44%)
2	*Ae. triseriatus* (LAC)	2 (100%)	1 (50%)
Onslaught (2007-2015)			
11	All species	7 (64%)	3 (27%)
5	*Culex* (WNV) **	4 (80%)	3 (60%)
1	*Ae. triseriatus* (LAC)	0 (0%)	0 (0%)

*Number of tests in which sufficient mosquitoes of a particular species group were captured to evaluate efficacy.

***Culex=Cx. tarsalis, Cx. restuans, Cx. pipiens*, and *Cx. salinarius*

Merus™ (ULV) Compared to Anvil® Merus™ is the first and only adulticide listed with the Organic Materials Review Institute (OMRI), for wide-area mosquito control in and around organic gardens and farms and meets the USDA's Natural Organic Program (NOP) standards for use on organic crops. Its active ingredient, pyrethrin, is a botanical insecticide. The product contains no chemical synergist. It is OMRI and NOP listed for use in environmentally sensitive areas.

We tested Merus and Anvil in campgrounds in Anoka County. Rum River Central Park in Ramsey was treated with Merus, Lake George Regional Park in Oak Grove was treated with Anvil® (for comparison with an operational material), and Ajawah Campground in Linwood Twp. was the untreated (control) site. Efficacy was evaluated using Mulla's equation that compares mean mosquito captures from treated and untreated sites on the first night of trapping (pre-treatment counts) with mean mosquito captures the second and third nights of trapping (post-treatment counts). Three CO_2 traps were placed three consecutive nights in each untreated control and treated site. Test materials were applied at sundown on the second night of trapping; CO_2 traps were placed 30 minutes after the treatments were completed at both treated locations and the untreated control location. CO_2 traps were placed at sundown the first and third trapping nights.

Adult mosquitoes (all species) were effectively controlled by Merus and Anvil immediately after treatment. Insufficient vectors were captured to evaluate efficacy. Efficacy appeared to wane 24 hours after treatment in both treated campgrounds (Table 5.5). Adult mosquitoes were very abundant before treatment. Both products significantly decreased adult mosquito abundance quickly after treatment with mosquitoes already moving in from surrounding areas within 24 hours after treatment.

Table 5.5 ULV Merus compared to Anvil 2016 (August 2-4)

		All mosquito species	
	Collection	Average CO_2 trap catch§	Efficacy*
Merus	Pre-treat	1,832.0 (±90.1)	---
	Post-treat	542.0 (±423.8)	81%
	Post-24 h	760.0 (±313.0)	36%
Untreated control	Pre-treat	258.7 (±127.5)	---
	Post-treat	394.7 (±28.8)	---
	Post-24 h	168.0 (±87.7)	---
Anvil	Pre-treat	1,213.0 (±203.6)	---
	Post-treat	80.0 (±26.3)	96%
	Post-24 hr	273.7 (±77.7)	65%

*Mulla's formula incorporates untreated control trap counts to correct for changes in the treated traps that are not due to the treatment

§Mean (±SE), n=3 CO_2 traps per campground site per sampling period

Equipment Evaluations

Helicopter Swath Analysis and Calibration Procedures for Larvicides Technical Services and field staff conducted five aerial calibration sessions for dry, granular materials during the 2016 season. These computerized calibrations directly calculate application rates and swath patterns for each pass so each helicopter's dispersal characteristics are optimized. Sessions were held at the municipal airport in Le Sueur, MN and Benson Airport in White Bear Lake, MN. Staff completed calibrations for seven different operational and experimental control materials. In total, eight helicopters were calibrated and each helicopter was configured to apply an average of four different control materials.

In 2015, an enclosed 24-foot trailer was purchased to house all the calibration gear, laboratory equipment, and blank calibration materials. Previously, we have stored equipment at multiple locations. This trailer protects equipment, keeps it better organized, and eliminates the need for multiple vehicles to carry all of the gear and materials.

In 2016, this trailer was modified to become a mobile workstation. The trailer now includes two sample weighing stations, an analysis station, product and equipment storage, aircraft communications, a weather station, and a power generator. This trailer can be towed to any location and be set up for operations in a short period of time. This improvement has greatly simplified and improved efficiency of helicopter calibrations sessions.

Malvern Laser: Droplet Analysis of Ground-Based Spray Equipment
In 2015, Technical Services purchased a Malvern Instruments Spraytec laser diffraction system to evaluate our adult mosquito equipment (backpacks, handheld, ATV-mounted and truck-mounted sprayers). Our previous equipment used for droplet measurement was 20 years old and was limited in the size range and quantity of droplets it could accurately measure.

Much of the work done in 2016 focused on developing new protocols, procedures, and processes for using the Spraytec system. There was a significant learning curve in understanding how to best use the equipment, which statistical features are most applicable to our spray systems, how to interpret the data output, and how to best evaluate each piece of equipment. MMCD worked with Malvern representatives to help them understand our processes and staff provided insight in to how best measure droplets of high volume spray systems.

A new air purge system was developed using a vacuum to blow a high volume of air away from the lens of the laser. This modification has kept the lens free of droplets and has allowed staff to conduct more equipment evaluations between lens cleanings. This change has improved the evaluation results because it eliminates any residue spray from affecting future tests.

Droplet Analysis of Ground-based Spray Equipment
Technical Services and MMCD staff use our 20 ft x 40 ft indoor spray booth to evaluate adulticide application equipment. In 2016, staff improved the spray booth by modifying the shape, reducing

the amount of stray air from entering booth, and rebuilding the structure which housed two large evacuation fans. By modifying the shape we were able to increase the draw efficiency of the fans which clears the booth of sampled droplets. By modifying the structure, we were able to increase the airtight integrity and maintain positive pressure to aid in the evacuation of sampled droplets. By rebuilding the fan structure, we were able to increase air flow and improve the waste spray collection by improving the droplet filtration system. The new filtration system removed backpressure and more effectively collected the small droplets that the spray systems produce.

This self-contained booth collects the adulticide spray droplets, which minimizes their release into the air following the calibration process, thus limiting any release of control materials into the environment.

Permethrin Backpack Droplet Evaluations MMCD staff developed a new prototype wand for our backpack sprayers to produce consistent 150-300 micron droplets. This droplet range is required by the product label for applications of our barrier spray. All District backpacks used for barrier treatments were modified to meet the label requirements.

ULV Droplet Evaluations Technical Services formed a workgroup to evaluate truck-mounted, UTV-mounted, backpack and handheld ULV generators. Using the Malvern laser, staff continued to improve sampling procedures and techniques to sample the multiple types of spray equipment. MMCD sub-sampled each equipment type and developed methods to evaluate each piece of equipment. The workgroup will continue to optimize spray systems with each individual control material and build our information database.

Optimizing Efficiencies and Waste Reduction

Evaluation of Transportation Options for Control Materials The District has continued to move towards more versatile options to transport materials to helicopter landing sites. The combination of one-ton pickups and flatbed trailers are now being used in most facilities to transport pallets of *Bti* to landing sites. The truck-trailer combination has more operational flexibility and is less expensive than large flatbed trucks. The pickups are used regularly in other field functions when not involved in helicopter operations.

Flatbed trucks are now being used to transport bulk materials. Bulk tote use for pre-hatch larvicides is increasing as the District moves towards more sustainable packaging options. The truck’s larger weight capacity, equipment storage space, and bed height work well for the new helicopter loading processes.

Helicopter Jet-A Fuel Cells MMCD, in conjunction with our helicopter contractor, has increased the number of large fuel cells (200-300 gallons) used in operations. These large fuel cells have been placed at District facilities or strategic locations to increase operational efficiency. In recent years, the District has moved from dedicated fuel trucks, where the tank required the full bed of the truck, to smaller fuel cells (91 gallon) that only require ¼ of the truck bed; therefore, this vehicle can be more easily used in other District operations. Additionally, the number of employees required at landing sites is reduced. The large fuel cells are now used to refill the smaller fuel cells. By refilling these cells at District facilities, it saves staff time and effort from running to/from regional airport locations to acquire fuel and paying a higher retail price at the airport.

Recycling Pesticide Containers MMCD continued to use the Minnesota Department of Agriculture's (MDA) pesticide container recycling program. This project focuses on properly disposing of agricultural pesticide waste containers, thereby protecting the environment from related pesticide contamination of ground and water.

Field offices collected their empty, triple-rinsed plastic containers at their facility and packaged them in large plastic bags for recycling. Each facility delivered their empty jugs to the Rosemount warehouse for pickup by the MDA contractor, Consolidated Container. MMCD arranged two semi-trailer pickups during the treatment season and staff assisted the contractor with loading of the recycled packaging materials. MMCD also assisted other small regional users to properly recycle their pesticide containers in conjunction with these collections. MMCD staff collected 2,998 jugs for this recycling program. The control materials that use plastic 2.5 gallon containers are sumithrin (172 jugs), *Bti* liquid (1,117 jugs), Altosid pellets (1,702 jugs) and other materials (7 jugs). The purchase of a portion of the Altosid pellets in bulk totes significantly reduced the number of jugs generated in 2016.

The District purchases Permethrin 57% OS concentrate in returnable drums. The manufacturer arranged to pick up the empty containers for reuse. In addition, these drums do not have to be triple-rinsed and thus reduces the District's overall generation of waste products. MMCD triple-rinsed and recycled numerous plastic drums and steel containers this past season. These 5- or 55-gallon drums were brought to a local company to be recycled or refurbished and reused.

The District's warehouse purchased mineral oil in 275 gallon bulk containers. Staff was able to reduce the overall number of 55-gallon drums purchased by 14 drums. These returnable containers do not have to be triple-rinsed and thus, reduces the District's overall generation of waste products.

Recycling Pesticide Pallets In 2016, MMCD produced over 1,959 empty hardwood pallets used in control material transportation. Technical Services worked with our vendors to uniquely mark their company's pallets and arrange for their return to the manufacturer for re-use. In doing so, MMCD reduced the need for the production of new pallets and helped to maintain lower control material costs for the District.

Bulk Packaging of Control Materials MMCD continued incorporating reusable packaging containers into our operations. The focus is to reduce the packaging waste of the various high use materials. MMCD can produce over 40,000 empty bags in an average year. We would like to eliminate a significant portion of these pesticide bags that cannot be recycled. Staff is attempting to keep these bags out of landfills, and instead directing them to garbage burner facilities where some public benefit of the generated waste can be realized.

The District continues to expand use of refillable totes in the helicopter loading operations. MMCD is working with three manufacturers to ship bulk larvicides in reusable pallet sized totes. In 2016, Clarke shipped all of our Natular G30 granules (75,200 lb) in 47 totes and reduced our packaging use by 1,880 bags. Central Life Sciences shipped a portion of Altosid pellets (22,000 lb) in 11 totes and reduced the packaging by 1,000 jugs. Valent BioSciences shipped a portion of MetaLarv granules (2,000 lb) in two totes which reduced packaging by 50 bags. Valent also sent a portion of VectoBac 12-AS liquid (528 gallons) in two bulk totes and reduced the packaging by 211 jugs. Staff was able to spend less time dealing with waste and the District eliminated 3,141 containers from entering the waste stream. MMCD is attempting to reduce the amount of time and effort spent handling packaging after the product is used, allowing staff to focus more time on our primary missions.

Return of Packaging Waste In 2016, Valent BioSciences agreed to take back all of the waste packaging of their products. Due to the large quantity (1,724,961 lb) and high bulk density of their products, Valent packaging is a significant portion of the waste produced annually by the District. This waste included product bags, pallets, boxes, and stretch wrap. All waste was packaged on specialized pallets and the manufacturer picked up these pallets periodically at our facility locations. Valent is working to recycle these multi-layered pesticide bags and thus, keep them out of landfills. MMCD greatly reduced their waste disposal services and estimates 19,320 lb was eliminated from our waste stream.

Hazardous Waste Collection In 2016, MMCD worked with the MDA to provide two regional sites for hazardous waste collection. The MDA provides a day each year that the public can properly dispose of any small quantity of hazardous waste free of charge. The District's Andover and Jordan facilities were used as collection points and MDA staff managed the safe handling of these materials. MMCD will continue to support this important public service to protect the environment.

2017 Plans – Product and Equipment Testing

Quality assurance processes will continue to be incorporated into the everyday operations of the regional process teams. Technical Services will continue to support field operations to improve their ability to complete their responsibilities most effectively. A primary goal will be to continue to assure the collection of quality information for all evaluations so decisions are based upon good data. We will continue to improve our calibration techniques to optimize all of our mosquito control equipment.

In 2017, we plan to repeat tests of MetaLarv S-PT against spring *Aedes* to evaluate its effectiveness as a spring pre-hatch larvicide. We also will repeat tests of adulticides, emphasizing vector control and effectiveness of barrier treatments.

Chapter 6 Supporting Work

2016 Highlights

- Completed transition to web data entry for adult mosquito inspections and treatments
- Continued outreach with beekeepers and worked with legislators
- Continued sustainability projects and investigations
- Citizen requests for late-season treatments increased, in keeping with frequent rain events

2017 Plans

- Continue training staff and building tools to make cloud-based data easy to access for analysis
- Build better tools in Webster for managing aerial treatment preparation and monitoring
- Rewrite larval data entry to integrate more easily with web forms
- Continue with sustainability efforts

2016 Projects

Data System Transition

This year marked a milestone for MMCD data systems: all field data entry is now done through our web-based system, "Webster." Field staff no longer need PDAs and we are moving more and more functionality onto smart phones, making information easily accessible to inspectors. Webster is also available to all staff through PCs or any device with a web browser.

Most 2016 work involved reviewing adult mosquito and black fly surveillance network processes and moving those to the Webster system, including adding/editing sample location information (including new employee sites), making sample tracking labels and lists, linking sample IDs, and presenting results in reports and online maps (internal) as well as our traditional printed (PDF) maps.

As a part of this work we reviewed how species ID data are stored in data structures, to ensure efficient storage but also support reporting of "zero-found" samples. We modernized adult species ID data schemas ("normalized") and worked on a similar plan for larval ID data. Adult species IDs are now entered through Webster. Larval species IDs are still entered with our legacy PC-based custom data system, and then pushed automatically to Webster. We are evaluating options for larval entry that will meet the need for speedy, high-volume entry.

Having Webster on smart phones has enabled more use of real-time GPS location for data entry. This was first used for container inspections in 2015 for auto-fill of address information from parcel maps, and the same approach is available for entering adult sample locations. We also added a "Mobile Map" function in Webster that allows field staff to see their current location relative to mapped larval or harborage sites, and retrieve information about nearby sites. Staff are also exploring ways to use Google "My Maps" to help track locations of important features and share that among crew members.

Basic adult treatment recording was also moved into Webster, and provides links to the adult surveillance that we require prior to each treatment. Material amounts and applicator information are recorded in the Webster form, and linked by reference to the paper maps that are still our definitive record of adulticide treatment.

Rain data available in Webster includes links to CoCoRahs rain gauge results and to National Weather Service and NOAA sites. We also display the most recent precipitation data from the National Weather Service - River Forecast Centers 4x4 km grid (Hydrologic Rainfall Analysis Project, HRAP) of precipitation estimates based on a combination of Nexrad radar and ground rain gauge measures. We have now found ways to download and manage River Forecast Center grid data so that we can use this to do things like create estimated rainfall histories (up to 10 years) for individual larval sites, or create lists of productive, air-treatment sites that just received over 1 inch of rain, and we look forward to working with this in 2017.

We continued to work with Houston Engineering, Inc. as our main consultant for building the Webster interface and supporting environment, and worked with SMB Systems for help with sample ID data structures. Most of the data underlying this Annual Report is collected through Webster.

Mapping

Wetland Mapping Wetland habitat maps are an essential tool for mosquito control work, and we use aerial photography as well as field visits to keep our maps of about 80,000 wet areas up-to-date. In 2016 we participated in a metro-wide air photo collection led by the Metropolitan Council and MnGeo, the state Geospatial Information Office. This provided much-needed easily accessible photo updates for the entire region, which became available in the fall and served as a base for staff's map updates.

In addition to wetlands, MMCD staff members map locations of many stormwater structures, such as street catch basins, large culverts or separators, and pond water level regulators, which provide larval habitat for species such as *Culex* vectors of West Nile virus and for *Ae. japonicus.* Over 24,000 structures are now mapped, in addition to 280,000 catch basins.

Public Web Map MMCD continues to make wetland locations and multi-year larval treatment history available through a public web map available at http://www.mmcd.org/is-my-site-treated/. Larval treatment records are automatically updated daily. This site is currently the only public-viewable part of our Webster online data environment, developed by Houston Engineering Inc. It uses basemap information from MetroGIS (Metropolitan Council) and aerial photos from MnGeo.

GIS Community MMCD staff continue to participate in MetroGIS. We are working with a group of MetroGIS members to update the MetroGIS Geocoder for public use. MMCD depends on the Geocoder for assigning locations to customer calls based on address information.

Climate Trends – Spring Degree Day Study

Spring temperatures described using degree-day (DD) accumulations continue to be a useful estimator for control activities. The DD model uses daily maximum and minimum air temperature (MSP airport) to compute a daily average. The difference between the average and the chosen base temperature of 40 °F (no larval growth per day) gives the 'heat units' accumulated each day for that base (DD_{base}). These are then summed from an assumed start date of January 1.

$$SumDD_{to\_date,\ base} = \sum_{(start\_date,\ to\_date)} (T_{avg} - baseT) \quad \text{where } T_{avg} = [(T_{max}+T_{min})/2]$$

Figure 6.1 shows the cumulative sum of DD_{40F} from Jan 1 by week of the year (DD value at end of week), for each year from 1996-2016. Week numbers were based on standard CDC weeks (week starts on Sunday, week 1 = first week with four or more days, modified so that all dates after Jan. 1 were in week 1 or higher).

The week totals with an outlined box mark the first week with ≥ 200 DD. This number was chosen empirically from these data as an apparent indicator of when spring *Aedes* larvae have sufficiently developed to warrant aerial treatment. In 2016 that DD total was reached by the end of week 15 (April 16), a fairly typical date compared with the last 19 years. After a significant precipitation event near the end of April (see Chapter 1, pp 2 and 4), aerial treatments for spring *Aedes* (gray boxes) began and were completed by May 5.

- First week with CumDD40 > 200   - Aerial Treatments for Spring spp. (many or few)   - Treatment on CumDD40 > 200 week

Week #	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Last date in week (2016)
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	
2	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	3	0	0	0	0	
3	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	3	0	0	0	0	
4	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	3	0	0	0	0	
5	0	0	0	0	0	0	2	3	0	6	0	0	0	0	0	0	3	0	0	0	0	
6	0	0	0	0	0	0	2	3	0	6	0	0	0	1	0	0	3	0	0	0	0	
7	0	0	1	0	0	0	2	3	0	6	0	0	0	1	0	0	3	0	0	0	0	
8	0	0	17	0	20	0	8	3	0	6	0	0	0	1	0	0	3	0	0	0	6	
9	0	0	17	0	39	0	8	3	2	6	0	0	0	1	0	0	3	0	0	0	6	
10	0	0	17	0	104	0	8	3	2	13	4	0	0	1	4	0	18	0	0	47	20	
11	12	0	17	2	104	0	8	19	3	13	4	20	2	30	49	6	135	0	3	76	104	
12	12	0	72	8	150	0	8	55	56	13	4	54	2	54	70	7	**306**	0	3	76	113	**Mar 26**
13	12	20	95	83	184	0	16	85	81	68	27	148	2	54	174	12	358	7	3	130	138	**Apr 2**
14	12	80	158	143	**209**	23	16	104	132	187	58	156	30	64	**236**	70	450	16	14	154	147	**Apr 9**
15	37	80	**234**	181	233	66	75	146	**209**	**300**	**209**	162	34	166	356	134	497	21	87	**290**	**244**	**Apr 16**
16	81	100	335	**231**	268	115	**220**	**233**	292	405	318	**281**	82	**249**	461	144	554	21	102	325	376	**Apr 23**
17	109	162	436	350	388	**213**	243	327	385	424	416	415	173	328	576	**200**	640	63	167	440	432	**Apr 30**
18	158	**225**	571	486	586	367	295	439	492	508	521	566	**213**	460	646	271	786	146	196	599	571	**May 7**
19	**220**	312	753	601	710	494	356	537	611	607	629	740	321	567	719	411	913	**267**	**302**	707	657	**May 14**
20	347	372	939	754	809	699	440	664	746	725	762	914	437	765	896	554	1112	434	378	812	790	**May 21**
21	492	490	1114	899	973	778	539	775	848	869	951	1075	545	923	1146	692	1280	570	527	979	1002	**May 28**
22	627	616	1210	1069	1111	910	755	939	1005	1059	1205	1274	690	1071	1341	905	1442	733	748	1148	1093	**Jun 4**
23	753	811	1345	1290	1305	1060	913	1093	1204	1292	1417	1457	873	1202	1512	1121	1681	868	944	1356	1408	**Jun 11**
24	967	1017	1558	1424	1462	1276	1117	1273	1388	1500	1633	1732	1059	1432	1721	1316	1881	1067	1111	1565	1635	**Jun 18**

281 Average CumDD40 Aerial Treatment Start
(we started treatments as early as 5 days prior to "Last date in week")

Figure 6.1 Cumulative Degree Days (base 40 °F, 4.4 °C) from January 1, MSP Airport.

Aerial treatments are not started until a sufficient number of sites are over threshold, seasonal inspectors are hired and helicopters calibrated. By holding off on treatment until the first rain, we try to control both snow-melt spring *Aedes* and any early floodwater *Aedes* hatch.

Evaluating Nontarget Risks

Spinosad (Natular) Nontarget Risk Information In recent years MMCD and TAB members worked on evaluating nontarget risk for Natular products, which use the biological control material spinosad (see Appendix C). Natular is registered by the U.S. EPA as a "Reduced Risk Pesticide" and is OMRI Listed® (Organic Materials Review Institute). MMCD uses Natular G30, an extended release (30 day) formulation, as an option for larval control in summer *Aedes* sites, as it has both a different mode of action and different manufacturer than *Bti* or methoprene. We are also testing Natular G, which has a shorter active period (up to 7 days) and lower cost.

A 2014 study conducted by District staff in spring, ephemeral ponds did not identify any large-scale nontarget impacts on physid snails, fingernail clams (sphaeriids), and fairy shrimp using Natular G; however, scuds (amphipods), the other organism of interest, were not detected in that study. At the TAB's recommendation staff undertook a second study targeting scuds, in conjunction with 2015 efficacy studies on *Cq. perturbans* with Natular G in cattail marshes. Results from two dates collected in that double-blind study, analyzed by TAB member Roger Moon, showed no measurably significant differences in amphipod (scud) populations related to treatment. Based on those results, and the likelihood that MMCD would not use Natular G in cattail sites, TAB members recommended at the February 2016 meeting that they do not believe that further sample processing is necessary. Samples from these studies have been stored for possible future processing if plans for Natular use change or other concerns are raised. We did not collect any nontarget samples with the additional efficacy tests of Natular G in cattail sites in 2016 (Chapter 5). Those tests showed inconsistent control of cattail mosquitoes and there are no current plans to use Natular G for that purpose operationally.

Previous Larvicide Nontarget Earlier publications and reports on Wright County Long-term Study and other studies on *Bti* and methoprene done under the direction of the Scientific Peer Review Panel (SPRP) continue to be available on the MMCD web site, mostly as PDF files. The address is http://www.mmcd.org/non-target-studies-bti/.

Pollinators and Mosquito Control The status of pollinator populations (e.g. honeybees, native bees, butterflies, flies, etc.) continues to be a public concern, and MMCD has continued efforts to ensure minimal negative effects on pollinators. Our biological controls for mosquito larvae pose no risk to bees. For controlling adult mosquitoes, the pyrethroids we use as fog or barrier spray on vegetation, when used according to label, are relatively low risk for bees. However, knowing where and when bees are active can reduce the chance of exposure and decrease risk further.

Since 2015, beekeepers who want to be eligible for compensation for losses due to pesticide exposure must register their hives through "beeCheck", a FieldWatch system (https://www.mda.state.mn.us/beekillcompensation). The hive locations can be seen on Drift Watch (mn.driftwatch.org/map) or by logging in as a FieldWatch registered applicator. We have been transferring these hive locations into our internal database/mapping system, and are continuing to explore methods to keep hive information up-to-date and easy to access for field staff, given that hives may be moved frequently for different forage conditions.

Two MMCD staff members participated in the MN Dept. of Agriculture Pollinator Summit in February 2016 (http://www.environmental-initiative.org/our-work/past-work/pollinators-summit) to better understand issues and work with other stakeholders to identify challenges and possible steps to be taken to help reverse pollinator decline.

Permits and Treatment Plans

National Pollutant Discharge Elimination System Permit A Clean Water Act - National Pollutant Discharge Elimination System (NPDES) permit is required for most applications of mosquito control pesticides to water, and MPCA procedures for Pesticide NPDES Permits are described at http://www.pca.state.mn.us/index.php/water/water-permits-and-rules/water-permits-and-forms/pesticide-npdes-permit/pesticide-npdes-permit-program.html. The checklist for mosquito control permits is given at http://www.pca.state.mn.us/index.php/view-document.html?gid=15671

In 2012, MMCD submitted a Pesticide Discharge Management Plan (PDMP) to the MPCA that described contact people, target pests and data sources, thresholds and management, and steps to be taken to respond to various types of incidents, submitted a Notice of Intent (NOI), and paid permit fees. This has been renewed annually. In 2016 we also completed the reapplication form and paid the reapplication fee as required every 5 years.

Comprehensive treatment listings have been prepared for the MPCA in fulfillment of the permit requirements and submitted annually. The listings included site-specific treatment history and a geospatial file of treatment locations. This is the same information that MMCD makes available for public view on MMCD's web site.

US Fish & Wildlife Service – Mosquitoes and Refuges MMCD works with the US Fish & Wildlife Service (FWS) regarding mosquito surveillance on and near FWS lands within the District. If rainfall, river levels, or other nearby surveillance indicates a need for sampling, work in the Minnesota Valley National Wildlife Refuge (MVNWR) is conducted following the stipulations of a Special Use Permit updated annually by the Refuge Manager. "Emergency Response Procedures" and "Pesticide Use Proposals" for the larvicide *Bacillus sphaericus* (VectoLex) and the adulticide sumithrin (Anvil) prepared in 2009 by FWS staff allow treatment of disease vectors if "a mosquito-borne disease human health emergency exists in vicinity of the Refuge" (agreed on by MDH, FWS, and MMCD) and such treatment "is found to be appropriate".

On May 2, 2016 MMCD requested permission to survey wetlands within the Soberg Waterfowl Production Area. The request was granted on May 5, 2016 and later that day MMCD staff surveyed seven wetlands within the Soberg WPA. Mosquito larvae were collected from three of the wetlands. The species collected included *Aedes vexans*, *Ae. excrucians*, and *Culiseta inornata*. Despite frequent summer rain, the Minnesota River remained within its banks inside the Minnesota Valley Nation Wildlife Refuge (MVNWR). Due to heavy demands on staff time throughout the mosquito season and the lack of Minnesota River flooding, MMCD did not request permission to survey wetlands in MVNWR for mosquito larvae in 2016.

Adult mosquito surveillance using CO_2 traps indicated *Ae. vexans* adults emerged shortly before the May 25 sampling date. Due to the frequency and amounts of rainfall in 2016, *Ae. vexans* collections were above average for much of the season. We observed four large increases in *Ae. vexans* capture rate near MVNWR in 2016 (5/25, 6/28, 8/9, 8/30). For traps near MVNWR, collections of *Ae. vexans* were greatest within one mile of the refuge.

CO_2 traps collections of *Cx. pipiens* and/or *Cx. restuans* were relatively low at locations near MVNWR in 2016. *Culex pipiens* and *Cx. restuans* serve as the enzootic or maintenance vectors of West Nile virus (WNV). Birds that move between the refuge and the surrounding area can be infected with WNV on or off the refuge then carry the virus to other areas and subsequently infect other mosquitoes on or near the refuge. *Culex tarsalis* numbers were generally low to moderate for most of the season near MVNWR at all but one location. The Eden Prairie trap (H291) consistently collected moderate to high numbers of *Cx. tarsalis* during most of June, July and August. Mosquitoes collected from traps near MVNWR were tested for WNV from the beginning of June through the end of September. There were two WNV positive samples from the area in 2016, one from a trap location near Fort Snelling State Park (FS1) July 26 and one from the east edge of Shakopee (S015) August 30.

Public Communication

Notification of Control The District continues to post daily adulticide information on its website (www.mmcd.org) and on its "Bite Line" (651-643-8383), a pre-recorded telephone message interested citizens can call to hear the latest information on scheduled treatments. Aerial larvicide treatment schedules are also posted on the web site and on the "Bite Line" as they become available. Information on how to access daily treatment information is regularly posted on Facebook and Twitter.

Calls Requesting Service Call volume in 2016 peaked in early August and again in late August, reflecting a surge in mosquito abundance in early and late August. Call volume and mosquito abundance dropped off dramatically just prior to Labor Day weekend (Fig. 6.2).

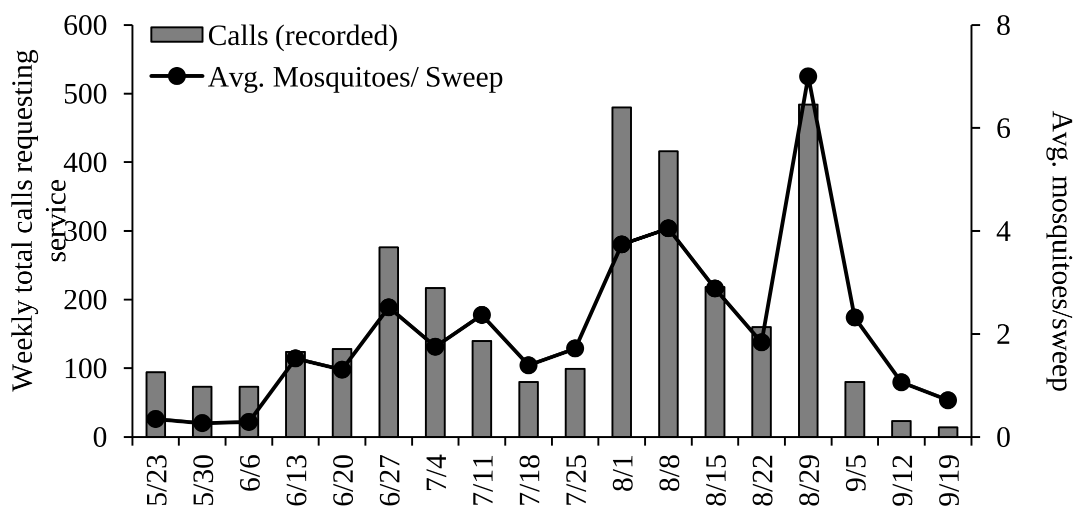


Figure 6.2 Calls requesting treatment of adults, and sweep net counts, by week, 2016.

Total requests for adult mosquito treatment increased substantially in 2016 compared to 2015 (Table 6.1). Call volume reached its peak two weeks prior to Labor Day weekend, reflecting a late-season surge in the human-biting mosquito population District-wide. Calls requesting site checks for larval mosquitoes doubled in 2016 compared to 2015. Although mosquito-borne Zika virus transmission does not occur in Minnesota, the specter of Zika virus and its associated effects dominated mosquito-related news nationally and to some extent, locally. Requests for limited or no treatment continue to reflect a District commitment to finding and mapping bee hive locations in the metro area.

Table 6.1 Yearly citizen call totals (including e-mails) by service request type, 2006-2016

	Number of calls by year										
Service request	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Check a larval site	610	393	220	197	164	626	539	609	1,068	447	886
Request adult treatment	854	867	1,375	594	1,384	1,291	1,413	1,825	2,454	1,633	2,499
Public event, request treatment	72	60	109	250	78	68	61	70	93	91	106
Request tire removal	170	208	257	253	335	316	419	351	434	371	378
Request or confirm limited or no treatment	[a]171	49	66	61	55	56	54	[b]151	[c]150	147	163

Note: 2013 call numbers corrected since previous TAB report
[a] Years where confirmation postcards sent to confirm restricted access property status
[b] Historic restriction "calls" moved into new system
[c] Bee hive locations added into call system to track restrictions

Curriculum in Schools Main Office and regional facility staff made presentations to 5,945 students in 51 schools during 2016. MMCD continued to deliver "Mosquito Mania," a three-day curriculum for upper elementary and middle school students. This curriculum was introduced to metro-area schools during the 2005-2006 school-year. "Mosquito Mania" builds on MMCD's relationship with schools by offering a standards-based approach to the subject of mosquitoes and their relationship to the environment. We continue to monitor changes in middle-school learning standards and make the adjustments necessary to keep the curriculum relevant and useful. Nearly one quarter of students reached by MMCD's school presentations visited learning stations set up as part of multi-school field days where a variety of public agencies gave short, science-based presentations throughout the day.

Social Media As part of an ongoing effort to notify residents when and where treatment is to take place, MMCD continues to build a presence on Facebook and Twitter. Anyone can sign up to receive MMCD tweets (@metromosquito). People can also "friend" Metropolitan Mosquito Control District on Facebook. MMCD currently has 360 followers on Twitter, up from 278 Twitter followers at the end of 2015, and 594 "Likes" on Facebook, up from 463 in 2015.

MMCD currently uses the service "GovDelivery" to give advance notification to District residents of adult mosquito treatments. In 2016, GovDelivery managed MMCD's direct treatment notification email lists. MMCD also works with GovDelivery to make efficient use of social media to reach people who are interested in finding out more about District treatment activities. GovDelivery is also used to distribute press releases and make announcements about job openings. In 2016 there were 4,129 subscribers to our GovDelivery email lists. In 2015, there were 3,177 subscribers. Again, up significantly from 2,503 distinct subscribers in 2014.

Sustainability Initiative

Ongoing impacts from decreasing natural resources and climate change have served to deepen MMCD's longstanding commitment to sustainability and social responsibility. In 2015, MMCD converted the sustainability steering committee into an established District team. In 2016, the team's work groups continued to address the following opportunity areas: 1) reducing energy usage; 2) reducing waste; 3) identifying and using renewable resources; and 4) promoting social responsibility and wellness.

Reduce Energy Usage We are currently reviewing our vehicle fleet with the goal of minimizing fuel usage while maximizing the amount of work completed for each mile driven. To achieve this long-term goal we are exploring how we can use better training for vehicle operators including better matching of vehicles to types of work. We are also exploring strategies to save electricity by encouraging teleconferencing for meetings, by providing training with webinars, and scripts to automatically shut down computers outside of work hours.

Reduce Waste We are working to reduce our waste stream through more effective recycling practices, through increasing organics composting, and by adopting reusable bulk control material containers.

Renewable Energy We are exploring renewable energy such as solar and wind generation to determine when and if such sources can provide cost effective replacements for current fossil fuel derived energy.

Social Responsibility and Wellness We are focusing on volunteering efforts inside and outside of work.

Professional Association Support

American Mosquito Control Association MMCD staff members continued to provide support for the national association, most notably Diann Crane's editorial assistance with the AMCA Annual Meeting Program.

North American Black Fly Association John Walz served as President and Program Chair for this group again in 2016 and Carey LaMere maintains the association's web site, http://www.nabfa-blackfly.org.

North Central Mosquito Control Association Mark Smith and Sandy Brogren serve on the Board of Directors of this regional association focused on education, communication, and promoting interaction between various regional organizations and individuals in Minnesota, North Dakota, South Dakota, Wisconsin, Iowa, and the Central Provinces of Canada. The 2017 meeting is April 6 and 7 in at Bunker Hills Regional Park, Andover, MN. Visit their website to learn more http://north-central-mosquito.org/WPSite/.

Scientific Presentations, Posters, and Publications

MMCD staff attends a variety of scientific meetings throughout the year. Following is a list of papers and posters presented during 2016 and talks that are planned in 2017. Also included are publications that have MMCD staff as authors or co-authors.

2016 Presentations & Posters

Brogren, S. 2016. Weather or not, we get mosquitoes: Seasonality of mosquito species. Presentation: North Central Mosquito Control Association Annual Meeting in Moorhead, MN.

Johnson, K. 2016. Zika: Surveillance and prevention. Presentation: North Central Mosquito Control Association Annual Meeting in Moorhead, MN.

Johnson, K. 2016. Zika Virus: Preparing for the U.S. invasion and implications for Minnesota. Presentation: Minnesota Environmental Health Association Annual Meeting in Brainerd, MN.

Johnson, K. 2016. Control methods for container inhabiting mosquitoes. Presentation: Minnesota Department of Agriculture Pesticide Applicator Recertification Workshop in St. Paul, MN.

Manweiler, S. 2016. Succession planning for sustaining a healthy, vibrant agency. Presentation: Michigan Mosquito Control Association Annual Meeting in Ann Arbor, MI.

McLean, M. 2016. Mosquito control and stagnant water. Presentation: 60th Annual Institute for Building Officials. University of Minnesota Continuing Education and Conference Center.

Nee, M. 2016. Mosquito clip art. Poster: American Mosquito Control Association Meeting in Savannah, GA.

Peterson, J. 2016. Flying into action: Helicopter larval treatments for MMCD. Presentation: American Mosquito Control Association Meeting in Savannah, GA.

Read, N. and K. Johnson 2016. Mosquito species maps: from *Aedes* to Zika. Presentation: Minnesota GIS/LIS Conference in Duluth, MN.

Read, N. 2016. Mosquito biology and control. Presentation as part of "Should we engineer the mosquito? Public forum" State University of New York, College at Oneonta, NY.

Smith, M. 2016. Sustainability - measuring the impact on mosquito control operations. Presentation: American Mosquito Control Association Meeting in Savannah, GA.

Smith, M. 2016. The technical side of mosquito control. Presentation: Minnesota Department of Agriculture Recertification Workshop in St. Paul, MN.

Smith, M. 2016. Increased communication & cooperation between public control operations and commercial mosquito control applicators. Presentation: North Central Mosquito Control Association Annual Meeting in Moorhead, MN.

Walz, J. and C. LaMere. 2016. MMCD black fly program update. Presentation: North American Black Fly Association Meeting in Laughlin, NV.

2017 Presentations & Posters

Johnson, K. 2017. Strategies for surveillance and control of *Culiseta melanura* and secondary vectors of eastern equine encephalitis by the Metropolitan Mosquito Control District. Presentation: American Mosquito Control Association Meeting in San Diego, CA.

Manweiler, S. 2017. Informing the public: How MADs are prepared to protect them from new and unknown vector-borne threats like Zika. Presentation: Michigan Mosquito Control Association Annual Meeting in Port Huron, MI.

Manweiler, S. 2017. WNV vector control in catch basins in Minnesota. Presentation: American Mosquito Control Association Meeting in San Diego, CA.

Smith, M. 2017. Incorporating bulk larvicide containers to improve the efficiency of mosquito control operations. Presentation: American Mosquito Control Association Meeting in San Diego, CA.

Soukup, A. 2017. Aerial perimeter treatments. Presentation: American Mosquito Control Association Meeting in San Diego, CA.

Publication

Kinsley, A., Moon, R., Johnson, K., Carstensen, M., Neitzel, D., Craft, M. 2016. Mosquitoes in Moose Country: a Mosquito Survey of Northern Minnesota. Journal of the American Mosquito Control Association 32(2): 83-90.

APPENDICES

APPENDIX A Mosquito and Black Fly Biology and Species List

Mosquito Biology

There are 51 species of mosquitoes in Minnesota. Forty-five species occur within the District. Species can be grouped according to their habits and habitat preferences. For example, the District uses the following categories when describing the various species: disease vectors, spring snow melt species, summer floodwater species, permanent water species, the cattail mosquito, and invasive or rare species.

Disease Vectors

Aedes triseriatus Also known as the eastern treehole mosquito, *Ae. triseriatus*, is the vector of La Crosse encephalitis (LAC). Natural oviposition sites are tree holes; however, adult females will also oviposit in water-holding containers, especially discarded tires. Adults are found in wooded or shaded areas and stay within ¼ to ½ miles from where they emerged. They are not aggressive biters and are not attracted to light. Vacuum aspirators are best for collecting this species.

Aedes japonicus This non-native species was first detected in Minnesota in 2007. By 2008, they were established in the District and southeast Minnesota. Larvae are found in a wide variety of natural and artificial habitats (containers), including rock holes and used tires. Preferred sites usually are shaded and contain organic-rich water. Eggs are resistant to desiccation and can survive several weeks or months under dry conditions. Overwintering is in the egg stage. Wild-caught specimens have tested positive for the LAC (Harris, C., et al, 2015. Emerging Infectious Diseases 21:4), thus, it is another potential vector of LAC in Minnesota.

Culex tarsalis *Culex tarsalis* is the vector of western equine encephalitis (WEE) and a vector of West Nile virus (WNV). In late summer, egg laying spreads to temporary pools and water-holding containers, and feeding shifts from birds to horses or humans. MMCD monitors this species using New Jersey light traps and CO_2 traps.

Other *Culex* Three additional species of *Culex* (*Cx. pipiens*, *Cx. restuans*, and *Cx. salinarius*) are vectors of WNV. All three use permanent and semi-permanent sites for larval habitat, and *Cx. pipiens* and *Cx. restuans* use storm sewers and catch basins as well. These three *Culex* vector species plus *Cx. tarsalis* are referred to as the *Culex*4.

Culex erraticus *Culex erraticus* normally a southern mosquito, has been increasing in our area over the past decade. In 2012 (a very warm spring and summer period), there were very high levels of adult *Cx. erraticus* in the District, and larvae were found for the first time since 1961 in permanent water sites with no emergent vegetation and edges with willow. *Culex erraticus* is a potential vector of eastern equine encephalitis (EEE).

Culiseta melanura *Culiseta melanura* is the enzootic vector of EEE. Its preferred larval habitat is spruce tamarack bogs, and adults do not fly far from these locations. A sampling strategy developed for both larvae and adults targets habitat in northeastern areas of the District, primarily in Anoka and Washington counties. Several CO_2 trap locations are specific for obtaining *Cs. melanura*; adult females collected from those sites are then tested for EEE.

Floodwater Mosquitoes

Spring *Aedes* Spring *Aedes* mosquito (12 species) eggs inundated with snowmelt runoff hatch from March through May; they are the earliest mosquitoes to hatch in the spring. Larvae develop in woodland pools, bogs, and marshes that are flooded with snowmelt water. There is only one generation per year and overwintering is in the egg stage. Adult females live throughout the summer, can take up to four blood meals, and lay multiple egg batches. These mosquitoes stay near their oviposition sites, so localized hot spots of biting can occur both day and night. Our most common spring species are *Ae. abserratus, Ae. punctor*, *Ae. excrucians*, and *Ae. stimulans*. Adults are not attracted to light, so human (sweep nets) or CO_2-baited trapping is recommended.

Summer Floodwater *Aedes* Eggs of summer floodwater *Aedes* (15 species) can hatch beginning in late April and early May. These mosquitoes lay their eggs at the margins of grassy depressions, marshes, and along river flood plains; floodwater from heavy rains (greater than one inch) stimulate the eggs to hatch. Overwintering is in the egg stage. Adult females live about three weeks and can lay multiple batches of eggs, which can hatch during the current summer after flooding, resulting in multiple generations per year. Most species can fly great distances and are highly attracted to light. Peak biting activity is as at dusk. The floodwater mosquito, *Ae. vexans* is our most numerous pest. Other summer species are *Ae. canadensis*, *Ae. cinereus*, *Ae. sticticus,* and *Ae. trivittatus*. New Jersey light traps, CO_2-baited traps, and human-baited sweep net collections are effective methods for adult surveillance of these species.

Cattail Mosquito

Coquillettidia perturbans This summer species is called the “cattail mosquito” because it uses cattail marshes for larval habitat. Eggs are laid in rafts on the surface of the water and will hatch in the same season. Larvae of this unique mosquito obtain oxygen by attaching its specialized siphon to the roots of cattails and other aquatic plants; early instar larvae overwinter this way. There is only a single generation per year, and adults begin to emerge in late June and peak around the first week of July. They are very aggressive biters, even indoors, and can disperse up to five miles from their larval habitat. Peak biting activity is at dusk and dawn. Adult surveillance is best achieved with CO_2 traps and sweep net samples.

Permanent Water Species

Other mosquito species not previously mentioned develop in permanent and semi-permanent sites. These mosquitoes comprise the remaining *Anopheles*, *Culex*, and *Culiseta* species. These mosquitoes are multi-brooded and lay their eggs in rafts on the surface of the water. The adults prefer to feed on birds or livestock but will bite humans. The adults overwinter in places like caves, hollow logs, stumps or buildings. As previously mentioned, the District targets disease vectors (the *Culex*4 species and *Cs. melanura*) for surveillance and/or control.

Invasive or Rare Species

Aedes albopictus This invasive species is called the Asian tiger mosquito. It oviposits in tree holes and containers. This mosquito is a very efficient vector of several diseases, including LAC. *Aedes albopictus* has been found in Minnesota, but it is not known to overwinter here. It was brought into the country in recycled tires from Asia and is established in areas as far north as Chicago. An individual female will lay her eggs a few at a time in several containers, which may contribute to rapid local spread. This mosquito has transmitted dengue fever in southern areas of the United States. Females feed predominantly on mammals but will also feed on birds.

***Psorophora* Species** Larvae of this genus develop in floodwater areas, are human-biting, and are not known to vector any disease. Four species occur in the District: *Ps. ciliata*, *Ps. columbiae*, *Ps. ferox,* and *Ps. horrida*. Although considered rare or uncommon, they have been detected more frequently since the mid-2000s. The adult *Psorophora ciliata* is the largest mosquito found in the District, and its larvae are predacious and even cannibalistic, feeding on other mosquito larvae.

Black Fly Biology

Life Cycle Females lay eggs directly onto the water or on leaves of aquatic plants and objects in rivers, streams, and other running water. Once they hatch, the larvae attach themselves to stones, grass, branches, leaves, and other objects submerged under the water. In Minnesota, black flies develop in large rivers (e.g. Mississippi, Minnesota, Crow, and Rum) as well as small streams. Most larval black flies develop under water for ten days to several weeks depending on water temperature. Larvae eat by filtering food from the running water with specially adapted mouthparts that resemble grass rakes. They grow to about 1/4 inch when fully developed; after about a week as pupae, they emerge as adults riding a bubble of air to the surface.

Female black flies generally ambush their victims from tree-top perches near the edge of an open area and are active during the day; peak activity is in the morning and early evening. Females live from one to three weeks, depending on species and weather conditions. They survive best in cool, wet weather. Studies done by MMCD show that the majority of black flies in the region lay only one egg batch.

Targeted Species (taken from Adler, P. et al, 2004)
Simulium venustum develops in smaller streams. It has one generation in the spring (April through early June), and is univoltine (one egg batch per year). Eggs overwinter and larvae begin hatching in April. Females can travel an average of 5.5-8 miles (maximum=22 miles) from their natal waterways. *Simulium venustum* is one of the most common black flies and probably one of the major biting pests of humans in North America.

Simulium johannseni develops primarily in the Crow and South Fork Crow rivers. It has one generation in the spring (April through May). Larvae develop in large, turbid, meandering streams and rivers with beds of sand and silt. Female adults feed on both birds and mammals.

Simulium meridionale develops in the Minnesota, Crow, and South Fork Crow rivers and is multivoltine with three to six generations (May- July). Adult females feed on both birds and mammals. Females will travel at least 18 miles from their natal sites and have been collected at heights up to 4,900 ft above sea level (0.932 miles).

Simulium luggeri develops primarily in the Mississippi and Rum rivers and has five to six generations a year. Eggs overwinter with larvae and pupae present from May to October. Three to five overlapping generations are produced annually. Host-seeking females can travel at least 26 miles from their natal waters and perhaps more than 185 miles with the aid of favorable winds. Hosts include humans, dogs, horses, pigs, elk, cattle, sheep, and probably moose.

Reference Cited

Adler, Peter H., Douglas C. Currie, and D. Monty Wood. 2004. *The Black Flies (Simuliidae) of North America*. Cornell University Press.

Species Code and Significance/Occurrence of the Mosquitoes and Black Flies in MMCD

Code	Genus	species	Significance/ Occurrence	Code	Genus	species	Significance/ Occurrence
Mosquitoes							
1.	*Aedes*	*abserratus*	common, spring	27.	*Anopheles*	*barberi*	rare, tree hole
2.		*atropalpus*	rare, summer	28.		*earlei*	common
3.		*aurifer*	rare, spring	29.		*punctipennis*	common
4.		*euedes*	rare, spring	30.		*quadrimaculatus*	common
5.		*campestris*	rare, spring	31.		*walkeri*	common
6.		*canadensis*	common, spring	311.	*An*. unidentifiable		
7.		*cinereus*	common, spring-summer				
8.		*communis*	rare, spring	32.	*Culex*	*erraticus*	rare
9.		*diantaeus*	rare, spring	33.		*pipiens*	common
10.		*dorsalis*	common, spring-summer	34.		*restuans*	common
11.		*excrucians*	common, spring	35.		*salinarius*	uncommon
12.		*fitchii*	common, spring	36.		*tarsalis*	common
13.		*flavescens*	uncommon, spring	37.		*territans*	common
14.		*implicatus*	uncommon, spring	371.	*Cx*. unidentifiable		
15.		*intrudens*	rare, spring	372.	*Cx.*	*pipiens/restuans*	common
16.		*nigromaculis*	uncommon, summer				
17.		*pionips*	rare, spring	38.	*Culiseta*	*inornata*	common
18.		*punctor*	common, spring	39.		*melanura*	uncommon, local
19.		*riparius*	common, spring	40.		*minnesotae*	common
20.		*spencerii*	uncommon, spring	41.		*morsitans*	uncommon
21.		*sticticus*	common, spring-summer	411.	*Cs*. unidentifiable		
22.		*stimulans*	common, spring	42.	*Coquillettidia*	*perturbans*	common
23.		*provocans*	common, early spring	43.	*Orthopodomyia*	*signifera*	rare
24.		*triseriatus*	common, summer, LAC vector	44.	*Psorophora*	*ciliata*	rare
25.		*trivittatus*	common, summer	45.		*columbiae*	rare
26.		*vexans*	common, #1 summer species	46.		*ferox*	uncommon
50.		*hendersoni*	uncommon, summer	47.		*horrida*	uncommon
51.		*albopictus*	rare, exotic, Asian tiger mosquito	471.	*Ps*. unidentifiable		
52.		*japonicus*	summer, Asian rock pool mosq.				
53.		*cataphylla**		48.	*Uranotaenia*	*sapphirina*	common, summer
118.		*abserratus/punctor*	inseparable when rubbed	49.	*Wyeomyia*	*smithii*	rare
261.	*Ae.* unidentifiable			491.	Males		
262.	Spring *Aedes*			501.	Unidentifiable		
264.	Summer *Aedes*						
Black Flies							
91.	*Simulium*	*luggeri*	treated, summer	96.	Other Simuliidae		
92.		*meridionale*	treated, summer	97.	Unidentifiable Simuliidae		
93.		*johannseni*	treated, spring				
94.		*vittatum*	non-treated, summer				
95.		*venustum*	treated, spring				

* Two *Aedes cataphylla* larvae were collected in April, 2008 in Minnetonka, MN

Genus Abbreviations for Mosquitoes

Aedes=Ae.	*Orthopodomyia=Or.*
Anopheles=An.	*Psorophora=Ps.*
Culex=Cx.	*Uranotaenia=Ur.*
Culiseta=Cs.	*Wyeomyia=Wy.*
Coquillettidia=Cq.	

APPENDIX B Average Number of Common Mosquitoes Collected per Night in Four Long-term NJ Light Trap Locations and Average Yearly Rainfall, 1965-2015. Trap 1, Trap 9, Trap 13, and Trap 16 have run yearly since 1965; in 2015, Trap 1 was discontinued and replaced with SF in 2016.

Year	Spring *Aedes*	*Aedes cinereus*	*Aedes sticticus*	*Aedes trivittatus*	*Aedes vexans*	*Culex tarsalis*	*Cq. perturbans*	All species	Avg. Rainfall
1965	0.10	0.22	0.06	0.01	107.54	8.76	1.28	135.69	27.97
1966	0.16	0.06	0.00	0.01	17.26	0.45	1.99	22.72	14.41
1967	0.31	0.27	0.25	0.03	85.44	0.96	4.93	95.5	15.60
1968	0.21	0.71	0.04	0.19	250.29	2.62	3.52	273.20	22.62
1969	0.15	0.23	0.01	0.03	20.39	0.57	3.57	30.12	9.75
1970	0.20	0.57	0.03	0.33	156.45	0.97	3.07	179.71	17.55
1971	0.87	0.42	0.12	0.11	90.45	0.50	2.25	104.65	17.82
1972	1.05	1.79	0.19	0.07	343.99	0.47	14.45	371.16	18.06
1973	0.97	0.68	0.03	0.04	150.19	0.57	22.69	189.19	17.95
1974	0.37	0.36	0.10	0.03	29.88	0.26	5.62	38.75	14.32
1975	0.28	0.63	0.44	0.17	40.10	6.94	4.93	60.64	21.47
1976	0.24	0.04	0.01	0.00	1.69	0.25	4.24	9.34	9.48
1977	0.14	0.07	0.00	0.02	21.75	5.98	7.42	34.07	20.90
1978	0.84	0.77	0.17	0.11	72.41	4.12	0.75	97.20	24.93
1979	0.29	0.21	0.03	0.48	27.60	0.29	2.12	35.44	19.98
1980	0.03	0.19	0.05	0.79	74.94	0.93	16.88	96.78	19.92
1981	0.05	0.14	0.13	0.69	76.93	1.50	4.45	87.60	19.08
1982	0.10	0.08	0.02	0.03	19.95	0.23	3.16	25.91	15.59
1983	0.15	0.08	0.02	0.04	45.01	0.67	3.44	53.39	20.31
1984	0.08	0.09	0.15	0.36	74.68	2.97	22.60	110.26	21.45
1985	0.07	0.00	0.02	0.01	21.02	0.33	4.96	28.72	20.73
1986	0.35	0.22	0.11	0.04	30.80	1.55	2.42	40.76	23.39
1987	0.00	0.09	0.01	0.17	29.91	1.18	1.52	37.43	19.48
1988	0.01	0.09	0.00	0.00	12.02	0.84	0.18	15.31	12.31
1989	0.05	0.35	0.01	0.26	13.13	1.60	0.17	21.99	16.64
1990	0.30	3.39	0.22	0.08	119.52	4.97	0.08	147.69	23.95
1991	0.11	0.56	0.15	0.26	82.99	1.17	0.45	101.33	26.88
1992	0.04	0.04	0.03	0.13	50.30	0.62	16.31	74.56	19.10
1993	0.03	0.24	0.10	1.15	50.09	0.96	10.90	72.19	27.84
1994	0.02	0.14	0.03	0.08	23.01	0.05	15.19	40.92	17.72
1995	0.04	0.28	0.02	0.29	63.16	0.42	6.79	77.71	21.00
1996	0.12	0.10	0.01	0.04	14.28	0.05	12.06	28.81	13.27
1997	0.09	0.64	0.14	0.63	39.06	0.14	2.03	45.35	21.33
1998	0.03	0.14	0.16	1.23	78.42	0.10	6.13	91.29	19.43
1999	0.01	0.28	0.09	0.11	28.24	0.06	1.74	33.03	22.41
2000	0.01	0.07	0.00	0.22	24.09	0.15	1.36	29.50	17.79
2001	0.05	0.41	0.32	0.10	20.97	0.27	1.01	26.26	17.73
2002	0.05	0.22	0.07	2.53	57.87	0.35	0.75	65.82	29.13
2003	0.04	0.15	0.43	2.00	33.80	0.13	1.59	40.51	16.79
2004	0.02	0.33	0.22	0.63	24.94	0.16	0.99	28.91	21.65
2005	0.05	0.11	0.17	0.42	22.27	0.17	0.57	25.82	22.82

Continued on next page

Year	Spring *Aedes*	*Aedes cinereus*	*Aedes sticticus*	*Aedes trivittatus*	*Aedes vexans*	*Culex tarsalis*	*Cq. perturbans*	All species	Avg. Rainfall
2006	0.05	0.08	0.14	0.01	6.73	0.08	1.85	10.04	18.65
2007	0.22	0.27	0.01	0.01	8.64	0.26	0.94	13.20	17.83
2008	0.38	0.32	0.17	0.01	8.17	0.10	2.01	12.93	14.15
2009	0.10	0.07	0.00	0.02	3.48	0.04	0.23	4.85	13.89
2010	0.07	0.08	0.06	0.17	16.18	0.23	0.36	26.13	24.66
2011	0.10	0.07	0.11	0.78	33.40	0.07	5.76	47.36	20.61
2012	0.04	0.03	0.15	0.21	21.10	0.04	4.01	30.39	17.53
2013	0.37	0.49	0.15	0.81	26.95	0.12	1.80	35.08	17.77
2014	0.12	0.32	0.19	0.44	32.42	0.20	2.18	41.72	23.60
2015*	0.02	0.26	0.01	0.46	27.73	0.06	3.77	36.00	24.02
2016	1.07	0.03	0.01	1.46	23.67	0.06	4.80	33.44	30.61

*Trap 1 discontinued in 2015 due to operator retirement. Data from three traps used since 2015: Trap 9, Trap 13, and Trap 16.

APPENDIX C Description of Control Materials Used by MMCD in 2016

The following is an explanation of the control materials currently used by MMCD. The specific names of products used in 2016 are given. The generic products will not change in 2017, although the specific formulator may change.

Insect Growth Regulators

Methoprene 150-day briquets Central Life Sciences
Altosid® XR Extended Residual Briquet EPA # 2724-421

Altosid briquets are typically applied to mosquito oviposition sites that are three acres or less. Briquets are applied to the lowest part of the site on a grid pattern of 14-16 ft apart at 220 briquets per acre. Sites that may flood and then dry up are treated completely. Sites that are somewhat permanent are treated with briquets to the perimeter of the site in the grassy areas. Pockety ground sites (i.e., sites without a dish type bottom) may not be treated with briquets due to spotty control achieved in the uneven drawdown of the site.

Coquillettidia perturbans sites are treated at 330 briquets per acre in rooted sites or 440 briquets per acre in floating cattail stands. Applications are made in the winter and early spring.

Methoprene pellets Central Life Sciences
Altosid® Pellets EPA# 2724-448

Altosid pellets consist of methoprene formulated in a pellet shape. Altosid pellets are designed to provide up to 30 days control but trials have indicated control up to 40 days. Applications will be made to ground sites (less than three acres in size) at a rate of 2.5 lb per acre for *Aedes* control and 4-5 lb per acre for *Cq. perturbans* control. Applications will also be done by helicopter in sites that are greater than three acres in size at the same rate as ground sites, primarily for *Cq. perturbans* control.

Methoprene granules Valent Biosciences
MetaLarv® S-PT EPA# 73049-475

MetaLarv S-PT consists of methoprene formulated in a sand-sized granule designed to provide up to 28 days control. Applications for control of *Cq. perturbans* and *Aedes* mosquitoes are being evaluated at 3 and 4 lb per acre.

Bacterial Larvicides

***Bacillus thuringiensis israelensis* (*Bti*) corn cob** Valent Biosciences
VectoBac® G EPA#73049-10

VectoBac corn cob may be applied in all types of larval habitat. The material is most effective during the first three instars of the larval life cycle. Typical applications are by helicopter in sites that are greater than three acres in size at a rate of 5-10 lb per acre. In sites less than three acres, the material is applied to pockety sites with cyclone seeders or power backpacks.

***Bacillus thuringiensis israelensis* (*Bti*) liquid** Valent Biosciences
VectoBac® 12AS EPA# 73049-38

VectoBac liquid is applied directly to small streams and large rivers to control black fly larvae. Treatments are done when standard Mylar sampling devices collect threshold levels of black fly larvae. Maximum dosage rates are not to exceed 25 ppm of product as stipulated by the MNDNR. The material is applied at pre-determined sites, usually at bridge crossings applied from the bridge, or by boat.

Bacillus sphaericus (Bs) Valent Biosciences
VectoLex® CG EPA# 73049-20

VectoLex CG may be applied in all types of larval *Culex* habitat. The material is most effective during the first three instars of the larval life cycle. Typical applications are by helicopter in sites that are greater than three acres in size at a rate of 8 lb per acre. In sites less than three acres, VectoLex is applied to pockety sites with cyclone seeders or power back packs at rates of 8 lb per acre. This material may also be applied to cattail sites to control *Cq. perturbans*. A rate of 15 lb per acre is applied both aerially and by ground to cattail sites in early to mid-September to reduce emergence the following June-July.

Natular® (spinosad) Clarke
Natular® G30 EPA# 8329-83

Natular is a new formulation of spinosad, a biological toxin extracted from the soil bacterium *Saccharopolyspora spinosad*, that was developed for larval mosquito control. Spinosad has been used by organic growers for over 10 years. Natular G30 is formulated as long release granules and can be applied to dry or wet sites.

Natular® (spinosad) Clarke
Natular® G EPA# 8329-80

Natular is a new formulation of spinosad, a biological toxin extracted from the soil bacterium *Saccharopolyspora spinosad*, that was developed for larval mosquito control. Spinosad has been used by organic growers for over 10 years. Natular G is formulated on corn cob as a short release granule designed for application (3.5 – 9 lb/acre) to wet sites.

Pyrethroid Adulticides

Permethrin Clarke
Permethrin 57% OS EPA# 8329-44

Permethrin 57% OS is used by the District to treat adult mosquitoes in known daytime resting or harborage areas. Harborage areas are defined as wooded areas with good ground cover to provide a shaded, moist area for mosquitoes to rest during the daylight hours.
Adult control is initiated when MMCD surveillance (sweep net and CO_2 trap collections) indicates nuisance populations of mosquitoes, when employee conducted landing rate collections document high numbers of mosquitoes, or when a large number of citizens complain of mosquito

annoyance from a given area. In the case of citizen complaints, MMCD staff conducts mosquito surveillance to determine if treatment is warranted. MMCD also treats functions open to the public and public owned park and recreation areas upon request and at no charge if the event is not-for-profit.

The material is diluted with soybean and food grade mineral oil (1:10) and is applied to wooded areas with a power backpack mister at a rate of 25 oz of mixed material per acre (0.0977 lb AI per acre).

Natural Pyrethrin Clarke
Merus™ 2.0 Mosquito Adulticide EPA# 8329-94

Merus is the first and only adulticide listed with the Organic Materials Review Institute (OMRI), for wide-area mosquito control in and around organic gardens and farms and meets the USDA's Natural Organic Program (NOP) standards for use on organic crops. Its active ingredient, pyrethrin, is a botanical insecticide. The product contains no chemical synergist. It is OMRI and NOP listed for use in environmentally sensitive areas.

Merus is used by the District to treat adult mosquitoes in known areas of concentration or nuisance where crop restrictions (organic growers) prevent treatments with resmethrin or sumithrin. Merus is applied from truck or all-terrain-vehicle mounted ULV machines that produce a fog that contacts mosquitoes when they are flying. Fogging may also be done with hand-held cold fog machines that enable applications in smaller areas than can be reached by truck. Cold fogging is done either in the early morning or at dusk when mosquitoes become more active. Merus is applied at a rate of 1.5 oz per acre (0.0048 lb AI per acre). Merus is a non-restricted use compound.

Natural Pyrethrin MGK, McLaughlin Gormley King
Pyrocide® Mosquito Adulticiding Concentrate 7369 EPA#1021-1569

Pyrocide is used by the District to treat adult mosquitoes in known areas of concentration or nuisance where crop restrictions prevent treatments with resmethrin or sumithrin. Pyrocide is applied from truck or all-terrain-vehicle mounted ULV machines that produce a fog that contacts mosquitoes when they are flying. Fogging may also be done with hand-held cold fog machines that enable applications in smaller areas than can be reached by truck. Cold fogging is done either in the early morning or at dusk when mosquitoes become more active. Pyrocide is applied at a rate of 1.5 oz of mixed material per acre (0.00217 lb AI per acre). Pyrocide is a non-restricted use compound.

Etofenprox Central Life Sciences
Zenivex® E4 Mosquito Adulticide EPA# 2724-807

Zenivex is used by the District to treat adult mosquitoes in known areas of concentration or nuisance. Zenivex is applied from truck or all-terrain-vehicle mounted ULV machines that produce a fog that contacts mosquitoes when they are flying. Fogging may also be done with hand-held cold fog machines that enable applications in smaller areas than can be reached by truck. Cold fogging is done either in the early morning or at dusk when mosquitoes become more active. Zenivex is applied at a rate of 1.0 oz of mixed material per acre (0.0023 lb AI per acre). Zenivex is a non-restricted use compound.

Esfenvalerate and Prallethrin MGK, McLaughlin Gormley King
Onslaught® FastCap Microencapsulated Insecticide EPA# 1021-1815

Onslaught (esfenvalerate, prallethrin, and the synergist PBO) is used by the District to treat adult mosquitoes in known daytime resting or harborage areas. Onslaught, a non-restricted use compound, is diluted with water (1:50) and applied to wooded areas with a power backpack mister at a rate of 25 oz of mixed material per acre (0.0026 lb AI per acre [0.0021 esfenvalerate and 0.0005 prallethrin]).

Resmethrin Bayer
Scourge® 4+12 EPA# 432-716

Scourge (resmethrin and the synergist PBO) is used by the District to treat adult mosquitoes in known areas of concentration or nuisance. Scourge is applied from truck or all-terrain-vehicle mounted ULV machines that produce a fog that contacts mosquitoes when they are flying. Fogging may also be done with hand-held cold fog machines that enable the applications in smaller areas than can be reached by truck. Cold fogging is done either in the early morning or at dusk when mosquitoes become more active. The material is applied at a rate of 1.5 oz of mixed material per acre (0.0035 lb AI per acre). Scourge is a restricted used compound and is applied only by Minnesota Department of Agriculture-licensed applicators.

Sumithrin Clarke
Anvil® 2+2 EPA# 1021-1687-8329

Anvil (sumithrin and the synergist PBO) is used by the District to treat adult mosquitoes in known areas of concentration or nuisance. Anvil is applied from truck or all-terrain-vehicle mounted ULV machines that produce a fog that contacts mosquitoes when they are flying. Fogging may also be done with hand held cold fog machines that enable applications in smaller areas than can be reached by truck. Cold fogging is done either in the early morning or at dusk when mosquitoes become more active. The material is applied at a rates 1.5 and 3.0 oz of mixed material per acre (0.00175 and 0.0035 lb AI per acre). Anvil is a non-restricted use compound.

Etofenprox Central Life Sciences
Zenivex® E4 EPA# 2724-807

Etofenprox is used by the District to treat adult mosquitoes in known areas of concentration or nuisance. Etofenprox is applied from truck or all-terrain-vehicle mounted ULV machines that produce a fog that contacts mosquitoes when they are flying. Fogging may also be done with hand held cold fog machines that enable applications in smaller areas than can be reached by truck. Cold fogging is done either in the early morning or at dusk when mosquitoes become more active. Etofenprox is applied at a rate of 1.0 oz of mixed material per acre (0.0023 lb AI per acre). Etofenprox is a non-restricted use compound.

APPENDIX D 2016 Control Materials: Active Ingredient (AI) Identity, Percent AI, Per Acre Dosage, AI Applied Per Acre and Field Life

Material	AI	Percent AI	Per acre dosage	AI per acre (lbs)	Field life (days)
Altosid® briquets [a]	Methoprene	2.10	220	0.4481	150
			330	0.6722	150
			440	0.8963	150
			1*	0.0020*	150
Altosid® pellets	Methoprene	4.25	2.5 lb	0.1063	30
			4 lb	0.1700	30
			0.0077 lb* (3.5 g)	0.0003*	30
MetaLarv™ S-PT	Methoprene	4.25	2.5 lb	0.1063	30
			3 lb	0.1275	30
			4 lb	0.1700	30
Natular™ G30	Spinosad	2.50	5 lb	0.1250	30
Natular™ G	Spinosad	0.50	5 lb	0.0250	7
VectoBac® G	*Bti*	0.20	5 lb	0.0100	1
			8 lb	0.0160	1
VectoLex® CG	*Bs*	7.50	8 lb	0.6000	7-28
			0.0077 lb* (3.5 g)	0.0006*	7-28
Permethrin 57%OS [b]	Permethrin	5.70	25 fl oz	0.0977	5
Onslaught FastCap® [c]	Esfenvalerate Prallethrin	6.40 1.60	25 fl oz	0.0021 0.0005	5
Scourge® [d]	Resmethrin	4.14	1.5 fl oz	0.0035	<1
Zenivex® E4 [e]	Etofenprox	4.00	1.0 fl oz	0.0023	<1
Anvil® [f]	Sumithrin	2.00	3.0 fl oz	0.0035	<1
Pyrocide® [g]	Pyrethrins	2.50	1.5 fl oz	0.00217	<1
Merus™ [h]	Pyrethrins	5.00	1.5 fl oz	0.0048	<1

[a] 44 g per briquet total weight (220 briquets=21.34 lb total weight)
[b] 0.50 lb AI per 128 fl oz (1 gal) (product diluted 1:10 before application, undiluted product contains 5.0 lb AI per 128 fl oz)
[c] 0.0135 lb AI per 128 fl oz (1 gal) (product diluted 1:50 before application, undiluted product contains 0.675 lb AI per 128 fl oz)
[d] 0.30 lb AI per 128 fl oz (1 gal) [e] 0.30 lb AI per 128 fl oz (1 gal) [f] 0.15 lb AI per 128 fl oz (1 gal)
[g] 0.185 lb AI per 128 fl oz (1 gal) (product diluted 1:1 before application, undiluted product contains 0.37 lb AI per 128 fl oz)
[h] 0.4096 lb AI per 128 fl oz (1 gal)
* Catch basin treatments—dosage is the amount of product per catch basin.

APPENDIX E **Acres Treated with Control Materials Used by MMCD for Mosquito and Black Fly Control, 2008-2016.The actual geographic area treated is smaller because some sites are treated more than once**

Control Material	2008	2009	2010	2011	2012	2013	2014	2015	2016
Larvicides									
Altosid® XR Briquet 150-day	294	225	174	205	165	189	193	186	168
Altosid® XRG	6,579	8,320	9,924	13,336	23,436	6,948	52	0	0
Altosid® Pellets 30-day	35,780	35,161	36,516	30,749	13,172	15,813	26,179	31,494	19,173
Altosid® Pellets catch basins (count)	195,973	219,045	227,611	234,033	226,934	246,300	239,829	248,599	240,806
MetaLarv™ S-PT	0	0	0	0	2,750	14,063	18,073	21,126	33,409
Natular™ G30	0	0	0	0	9,524	15,000	14,950	8,840	13,023
Altosid® XR Briquet catch basins (count)	40	0	0	0	458	375	437	450	448
VectoLex® CG granules	6	0	0	0	0	2,330	3,064	3,777	6,076
VectoMax® CG granules	182	5	0	0	0	0	0	0	0
VectoBac® G *Bti* corn cob granules	122,251	151,801	250,478	201,957	207,827	150,280	255,916	258,148	234,120
VectoBac® 12 AS *Bti* liquid (gal used) Black fly control	2,063	2,181	2,630	3,817	3,097	3,878	4,349	4,351	3,112
Adulticides									
Permethrin 57% OS Permethrin	8,272	4,754	8,826	7,544	8,578	9,020	8,887	6,093	8,128
Scourge® 4+12 Resmethrin/PBO	64,142	12,179	27,794	24,605	8,078	37,204	44,890	19,767	23,072
Anvil® 2 + 2 Sumithrin/PBO	35,734	7,796	26,429	29,208	27,486	36,000	31,381	27,183	16,399
Pyrenone® Adulticide	2,214	943	2,560	0	0	0	0	0	0
Pyrocide® Adulticide	299	0	0	0	0	0	5,338	3,605	0
Zenivex® Etofenprox	0	0	0	0	0	0	0	10,380	34,984

APPENDIX F Graphs of Larvicide, Adulticide, and ULV Fog Treatment Acres, 1984-2016

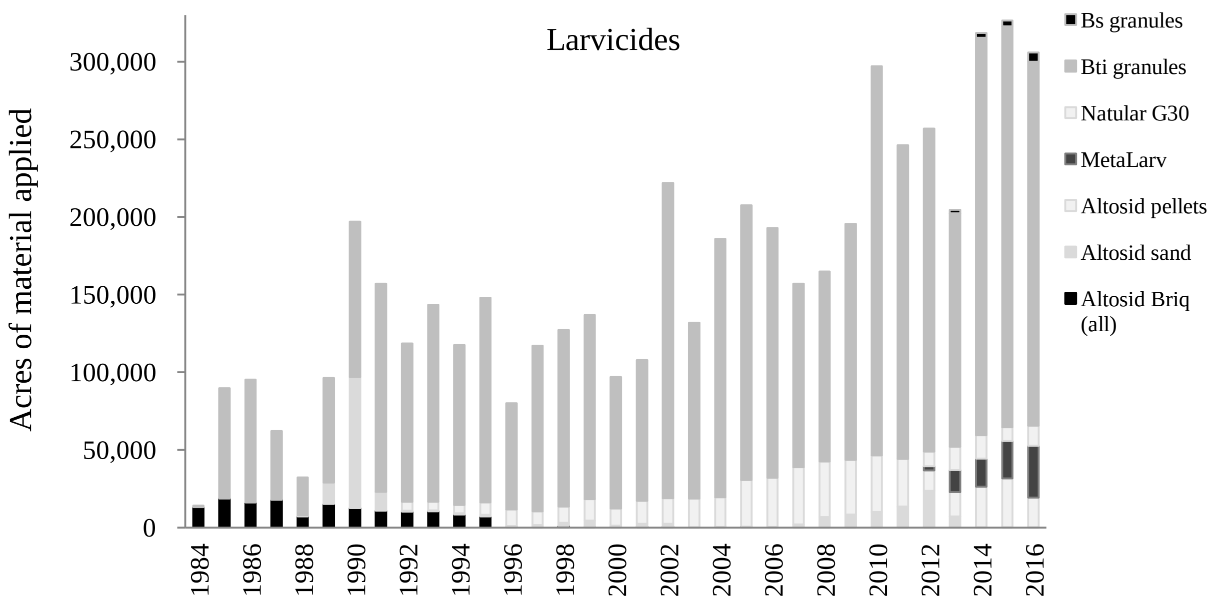


Figure F.1 Summary of total acres of larvicide treatments applied per year since 1984. For materials that are applied to the same site more than once per year, actual geographic acreage treated is less than that shown.

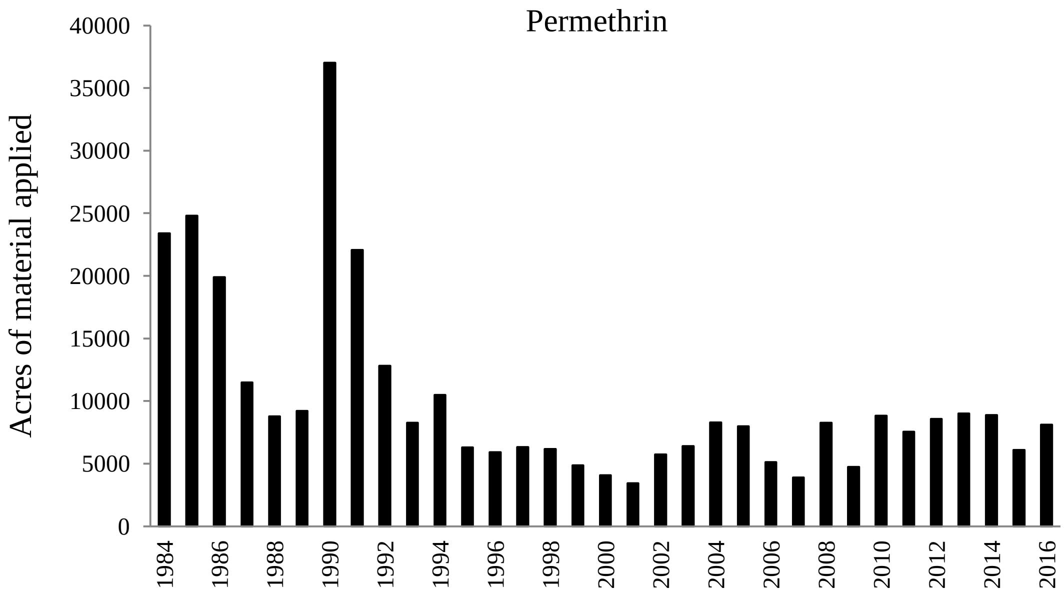


Figure F.2 Summary of total acres of permethrin treatments applied per year since 1984. This material may be applied to the same site more than once per year, so actual geographic acreage treated is less than that shown.

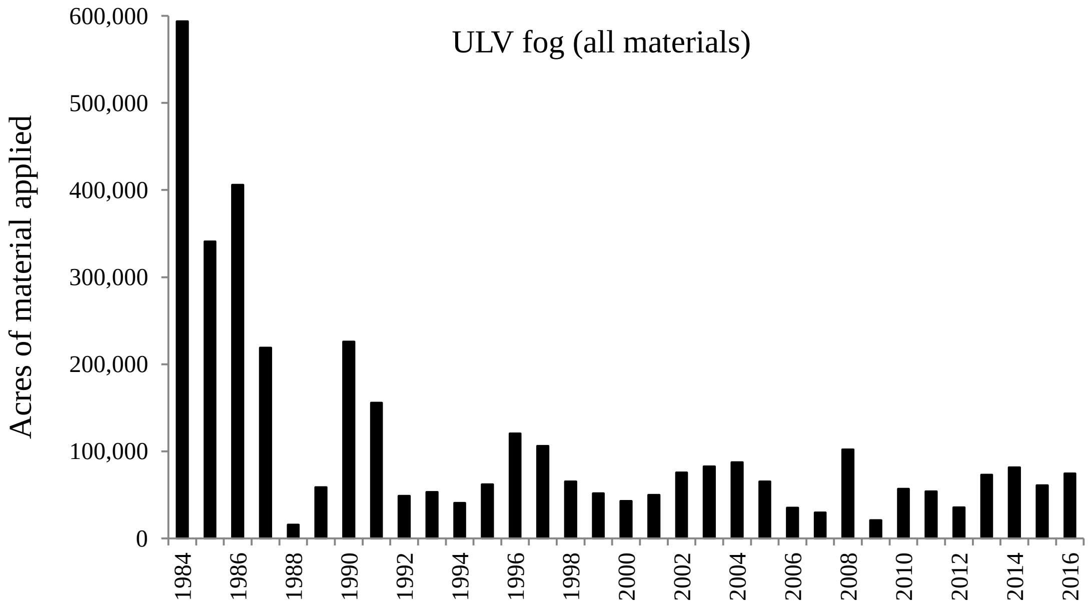


Figure F.3 Summary of total acres of ULV fog treatments applied per year since 1984. These materials may be applied to the same site more than once per year, so actual geographic acreage treated is less than that shown.

Appendix H MMCD Technical Advisory Board Meeting February 21, 2017

TAB Members Present:
Sarma Straumanis, MN Department of Transportation
Christine Wicks, MN Dept. of Agriculture
Don Baumgartner, US EPA (remote link)
Roger Moon, University of Minnesota
John Moriarty, Three Rivers Park District
David Neitzel, MN Department of Health
Robert Sherman, Independent Statistician
Vicky Sherry, US Fish and Wildlife Service
Susan Palchick, Hennepin County Public Health
(Absent: reviewed document and contributed comments):
Phil Monson, MN Pollution Control Agency
Gary Montz, MN Dept. of Natural Resources

MMCD Staff in Attendance: Stephen Manweiler, Nancy Read, Sandy Brogren, Diann Crane, Janet Jarnefeld, Kirk Johnson, Carey LaMere, Mike McLean, Mark Smith, John Walz, Molly Nee, Jennifer Crites, Arleen Schacht

Guests: Franny Dorr (MDH), Elizabeth Schiffman (MDH), Molly Peterson (MDH), Jenna Bjork (MDH)

(Initials in the notes below designate discussion participants)

Welcome and Call to Order
Chair Dave Neitzel called the meeting to order at 12:30 p.m. All present introduced themselves. Dave then introduced MMCD Executive Director, Stephen Manweiler.

MMCD Update
Stephen Manweiler discussed some of the challenges facing the District. We have had a lot of personnel turnover due to retirement, mostly in field positions in 2016. We are dealing with succession planning like many other agencies. Another challenge we are dealing with is funding. Our Commission had embarked on a plan to spend down our accumulated reserves gradually, but they have been depleted more rapidly in the past few years with high rainfall. We have a small increase in levy for 2017 but still need to reduce expenses by about $1.2 million in order to balance. He described seven options that are being evaluated for savings and impact.

2016 Mosquito Season Highlights
Sandy Brogren started the Season Overview with a description of the precipitation and temperature patterns for 2016. We had above average temperatures every month of the year, continuing a streak since fall of 2015. April was fairly dry, but August was our wettest month and set records for the metro area. She described the main groups of mosquito species we encounter in the District, and how their biology relates to habitats and rainfall. Spring *Aedes* had a late start with little snow melt and very low numbers. We have not had high numbers of this

species since 2008. Summer *Aedes* were more plentiful later in the year corresponding with high rainfall. The peak date collection in August was the 7th highest in our history. *Coquillettidia perturbans* were above average this year. Sandy presented an analysis of rain and *Cq. perturbans* populations done by Roger Moon. She discussed what information is available for predicting conditions for the coming year.
SP – influence of snow pack – could the lack of snowpack affect the viability of the spring *Aedes* eggs? Any models? SB, NR – we know snow is important but have not found a good source of data or models to use.

Nancy Read discussed control work done in 2016 and plans for 2017. Spring *Aedes* control used over 40,000 acres of *Bti* treatments, and included some areas outside the "Priority 1" area ("P1") with the highest human population density. Cattail treatments for *Cq. perturbans* were done primarily with 30-day release methoprene pellets. Treatment for this species was also done in some areas outside the P1 boundary. Summer *Aedes* treatments used *Bti* immediately after rain, but also up to 15,000 acres had active pre-hatch treatments with 30-day release methoprene or spinosad products for the first half of the summer, when we usually get more rain. However in 2016 more rain occurred in the second half of the summer, when the pre-hatch treatments were no longer active, so more sites were treated with *Bti*. Rainfall data available from the National Weather Service River Forecast Center has been downloaded into MMCD's data system and shows how the Aug. 11, 2016 rainfall was exceptional when compared with the last five years. In order to reduce cost in 2017, MMCD is considering options such as eliminating treatments in P2, increasing the spring *Aedes* threshold, cutting back on the use of pre-hatch materials, and targeting treatments more closely to areas within sites that have the most mosquitoes.
RM – you should look into drones for sampling, there were examples at the International Congress of Entomology. Other TAB members commented on limitations using drones.
RS – What are you sampling for? You could do bioassays to determine the amount of control material (Bti) in the water? Can do serial dilutions for better estimates. NR, SM – yes, we do some bioassays. CM – Dept. of Ag. does not test for Bti.
RM – as you are looking at cost cutting, think about the costs of collecting and processing samples and data as well as cost of control. NR – need data to evaluate effects of control cuts.
SP – for partial treatments, are the pilots ok with that? Harder to fly a perimeter pattern. NR – GPS guidance helps. SM – Helicopter contractor has said it's ok.
DN – concerned about spring *Aedes* cuts, which include potential vectors of Jamestown Canyon virus; there have been two human cases in Sherburne County, so P2 treatments particularly in Anoka County seem warranted.
SP – Do you have more complaints about too many mosquitoes vs. the helicopter is flying over our house? NR – mosquito annoyance.

Vector-Borne Diseases
Janet Jarnefeld described tick results that are available. High warmth has extended season, 2015 and 2016 activity March through December. Tick activity for 2017 has started already in February. Record numbers of ticks, record ticks per mammal, and record number of positive sites were observed in 2016; these numbers have increased in each of the last three years.
DN – looks like there were high populations of small mammals as well? JJ – yes, not a record, but larger than some earlier years.

Kirk Johnson reported that WNV cases were similar nationally in 2016 as 2015, about half of those reported were neuroinvasive, which suggests that there is actually under-reporting of non-neuroinvasive WNV. Minnesota had 66 cases, 13 in MMCD. We had three cases of LAC statewide, only one in MMCD; the number of cases seem low for the amount of rainfall received. We work to prevent cases by recycling tires and eliminating other larval habitats.
DN – the final WNV case count has gone up more (over 70), Getting results this year has been slower due to Zika analyses. It was a busy year for WNV.
BS – is WNV related to horse distribution? KJ – not really, but related to *Cx. tarsalis* distribution, most cases are in the prairie states. In urban areas the vectors are *Cx. pipiens* in the north and *Culex quinquefasciatus* in the south.
RM – how would case map change if it was incidence, not just cases? KJ – would show much higher in western MN similar to Dakotas. <u>RM – put those maps side by side in 2017 TAB report.</u>

Kirk continued with an update on Zika virus and its distribution in the Western Hemisphere. Puerto Rico has had an extraordinary outbreak with over 30,000 cases. In South Florida there were 214 domestically exposed cases and six in Texas (Brownsville). Overall there have been 1,400 pregnant women exposed (travel or domestic) in US, most have not delivered so no impact statistics yet. Kirk discussed the current info on the mosquito vectors of Zika, and the collections of one of those vectors, *Ae. albopictus*, at a tire recycling site in the District. We were surprised to find *Ae. albopictus* larvae in November.
JM – (comment on aerial photo of tire recycler where *Ae. albopictus* found) is that Eagle Creek? KJ – yes, trout stream, we can't do adulticiding at that location, trying to do control by removing larval habitat, challenging environment with lots of human-associated junk and container habitat. (SP left at this time)

Kirk gave an update on the federally-funded Upper Midwestern Center of Excellence in Vector-borne Diseases now established based in UW Madison. The Center is in touch with MDH and starting to set up connections with others in MN.
TAB members discussed contacts regarding the Center, and locations of the other centers set up under this funding.

Break 1:50-2:10 p.m.

Black Fly Season
John Walz described the Black Fly Program, including the small stream and large river sites checked and treated. Spring stream treatments were low with low spring runoff amounts. The large river levels stayed high much of the year, and eventually flooded in late August to the point where we could no longer sample and treat. Unusually, the larval populations in the Mississippi River did not reach threshold except for two times, and the adult populations were also relatively low. We also continue to monitor the Mississippi for nontarget organisms and have found that there have been no large-scale changes in the macroinvertebrate community.

RM – p 56 in report, maps, looks like mostly coming from South Fork Crow River? JW- yes, mostly *S. meridionale*. RM – is there a way to improve surveillance and improve control? Field application is improved if you know the species present. CL – that is a border site, some of those are probably coming from portions of river outside MMCD.

Adulticides - Merus™

Stephen Manweiler discussed characteristics and tests of a new adulticide formulation of natural pyrethrin that can be used in organic farm situations. Tests were run on three campgrounds in Anoka County, sampling before, immediately after and one day after treatment. Merus was compared with Anvil 2+2 (PBO-synergized pyrethroid) and untreated control. Both adulticides were able to reduce mosquito populations after treatment.
JM – what is the usual buffer around an organic field? SM – normally take swath width and double it, 300 ft for a truck fog application.
RM – Ground applied? That swath would be small.

Pollinators Update

Mike McLean outlined how MMCD has taken a number of steps to align ourselves with needs for pollinator protection. We are particularly concerned about knowing where honey bee hives are located so we can effectively avoid them and not be surprised when doing field work. We've worked with the beekeepers association to help them feel comfortable communicating with us, and are also using the "DriftWatch" site where they can register for compensation.
CW – two claims were paid in 2015, there are some in 2016 still pending, most seem to be soybean aphid treatments, not mosquito-control related.
RS – hard to imagine how a whole colony could be affected by one passing spray?
CW – it can be both direct and indirect effects, often it is materials brought back into the hive by foraging bees.
RS – seems like it would have to be a large spray application to affect enough bees to show up? I've tried extinguishing a colony of wasps, can be hard to do.

Mike showed the map of current beehive areas on the maps, and said he gets an e-mail whenever something added. We currently have 225 hive records on our maps, DriftWatch currently has more like 125.
JM – what if someone calls from area where hives not allowed? MM – we are not trying to be an enforcer, we just record for our use.

Mike emphasized that we train our applicators to understand their environment, follow the label (don't apply to flowering plants), and map what we know.
RM – I commend you for these efforts. Regarding mapping hives, hobby people keep hive in yard, but others move often, how do you keep points up to date? MM – that's a challenge. We may need to actively update the maps.
RS – people who have talked to me have been concerned about bees forming colonies in their house? MM – sometimes beekeepers have to find ways to herd their bees back into a hive. It's not easy.
RM – suggest you not use the word "pesticide", use "insecticide" instead, much more specific.
CW – FieldWatch map and application requires hive owners to renew every year, so that helps keep outdated info off the map. Important both for bee owners and for applicators trying to get their work done and avoid hives.
RS – any issue with Africanized bees? RM – further south than *Ae. aegypti*, don't need to worry about that.

Discussion and Resolutions

Chair Dave Neitzel asked for further discussion and any resolutions that the TAB would like to make to communicate with the MMCD Commissioners.

RS – organization is running so well, running out of commendations.

DN – recognize that MMCD is looking for ways to cut costs, but I still have concerns about control of vector mosquitoes, such as raising the spring Aedes threshold and reduced control of vectors through reduced prehatch applications. [ed. note: *Bti* applications are typically done when floodwater mosquitoes present, vector mosquitoes often 1-2 weeks later in the water, *Bti* would no longer be active but prehatch still provides control.]

RS – some tests are being done on genetic control of mosquitoes, for example through CRISPR, assume staff are keeping track of new technologies? KJ – so far those technologies are focused on vector species of more impact than what we have in MN.

RS – would like to hear more about that in the future. SM – several papers were presented at AMCA on similar topics, including sterile male release.

RM – you would need a quadruple PR office if you talk about doing any of that in the metro area. SM – if something came up that might help with *Ae. albopictus* we might look into that further.

RM – for Resolution, want to emphasize importance of looking at all options for cost savings, while still maintaining vector control and keeping environmental effects low. All of these are important.

MOTION: The TAB commends MMCD for its efforts to improve the cost efficiency of its programs while continuing to protect public health through vector control, and considering long-term environmental effects of its programs.

Motion made by RM, second by JM.

Approved.

TAB Membership, suggestions

NR asked if there were any thoughts about candidates for additional TAB members representing areas of concern or expertise, or enabling transition if some members are considering retirement or leaving the Board. Some names were suggested for expertise in pollinators or aquatic science, and the idea was also put forward to look for input on recent advances in graphic display methods and statistical tools.

TAB adjourned 3:17 p.m. (motion by JM, second by RS)

Next chair will be the representative from MN Dept. of Agriculture (Christine Wicks).

Our Vision

To be the leading mosquito abatement district in the world

technology • public service • stewardship • effectiveness • partnership • innovation

Our Mission

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.

Our Values

We value integrity, trust, cooperation, respect and competence in our interactions with colleagues and customers.

mmcd
METROPOLITAN MOSQUITO CONTROL DISTRICT

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