Metropolitan Mosquito Control District

2018 Operational Review & Plans for 2019

Annual Report to the Technical Advisory Board

Artwork by Kathy Beadle

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 2019

Mike Gamache	Anoka County
Mandy Meisner	Anoka County
Robyn West	Anoka County
James Ische	Carver County
Tom Workman	Carver County
Thomas Egan	Dakota County
Mary Liz Holberg	Dakota County
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Mary Jo McGuire	Ramsey County
Jim McDonough	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.

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Donald Baumgartner	US EPA
Stephen Kells	University of Minnesota
Phil Monson	Mn Pollution Control Agency
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Metropolitan Mosquito Control District Contributing Staff

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

Cover art provided by Kathy Beadle,
Field Operations Supervisor, Oakdale Facility

METROPOLITAN MOSQUITO CONTROL DISTRICT

Website: www.mmcd.org

Metro Counties Government Center
2099 University Avenue West
Saint Paul, MN 55104-3431

Phone: 651-645-9149
FAX: 651-645-3246
TTY use Minnesota Relay Service

April 24, 2019

Dear Reader:

The following report is the Metropolitan Mosquito Control District's (MMCD) 2018 Operational Review and Plans for 2019. It outlines program operations based on the policies set forth by the Metropolitan Mosquito Control Commission (MMCC), MMCD's governing board of elected county commissioners.

The report has been reviewed by the Commission's Technical Advisory Board (TAB). TAB's charge is to comment on and make recommendations for improvements in the District's operations, on an annual basis. The minutes and recommendations from the TAB meeting on February 13, 2019 are included in this report.

TAB's recommendations and report were accepted by the Commission at their April 24, 2019 meeting. The Commission approved the MMCD 2018 Operational Review and Plans for 2019 and thanked the TAB for their work.

Please contact us if you would like additional information about the District.

Sincerely,

Stephen A. Manweiler
Executive Director

DEPARTMENT OF AGRICULTURE

April 3, 2019

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

Dear Commissioner Workman,

The Technical Advisory Board (TAB) met on February 13, 2019 to review and discuss MMCD operations in 2018 and plans for 2019. 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 resolutions.

1. The TAB supports the program presented in the 2018 Operational Review and 2019 Plan and acknowledges the efforts of the MMCD staff on its presentation.

2. The TAB commends MMCD on its review of the Endangered Species Act and its impact on MMCD activities. The review of the rusty patched bumble bee biology and distribution in relation to current mosquito control operations showed low risk to the bees. MMCD should stay in contact with the USFWS to keep its high potential zone map up to date and be aware of new USFWS guidance regarding this species, and to stay informed of any new listed species in the District that might be impacted by operations.

3. That the MMCD produce written documentation detailing the informal consultation with USFWS on potential impacts of mosquito control operations on the rusty patched bumble bee, in consultation with USFWS staff, and that this be made available to the public.

4. The TAB commends MMCD on evaluating the potential importance of *Cx. pipiens* as a human West Nile virus vector locally, and encourages continued evaluation of this species.

Sincerely,

Christine Wicks

Christine Wicks
Chair, Technical Advisory Board
Agricultural Chemical Unit Supervisor, Inspection Unit 2
Pesticide & Fertilizer Management Division
Minnesota Department of Agriculture

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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 2018 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 2019 as we continue to provide an integrated mosquito management program for the benefit of metro area citizens.

Mosquito Surveillance

The cold spring, punctuated by a mid-April blizzard, set the stage for a very slow start to the mosquito season. Ice-out on Lake Minnetonka did not occur until May 5, tied for latest ice-out date since 1857. The first larval sample was taken on April 24, much later in the season than usual. The spring brood which normally hatches over a three-month period was compressed into one month. Conditions quickly warmed up in May and the first 100-degree day occurred on Memorial Day. June, July, and September had more rainfall than normal, while August was 2.4 inches below normal. In addition to the spring *Aedes* brood, there were twelve summer rainfall events sufficient to produce summer *Aedes* broods – three large broods and nine small- to medium-sized broods.

Adult mosquito populations were largest on the July 2 sampling date. A large emergence of summer *Aedes* and *Cq. perturbans* occurred at the same time. Lack of rainfall in August led to a nearly mosquito-free end to the summer. Three mosquito species previously considered rare in the District are on the rise. *Anopheles quadrimaculatus*, historically a vector of malaria in Minnesota, reached the highest levels recorded in the District (5,629 specimens). Also on the rise were *Psorophora ferox* and *Ps. horrida*. We have been collecting increasing numbers of *An. quadrimaculatus* and these *Psorophora* species since 2010.

Mosquito and Tick-borne Disease

District staff provide 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 anaplasmosis (HA). In 2018, the Minnesota Department of Health reported 19 cases of WNV in District residents. MMCD tested 842 mosquito pools using the RAMP® method, 132 of which were positive for WNV. The WNV cycle received an early boost from the warm wet conditions of the first half of the 2018 season. The WNV infection rate in *Culex* species increased to 9.14/1,000 mosquitoes tested during the week of July 23 (Figure 2.4). Cooler temperatures during a three week stretch in July caused the infection rate to dip in late July and early August; however, the return of hot weather resulted in amplification of WNV to the highest level ever recorded in the District at 18.87/1,000 during the week of August 27. There were no cases of LAC diagnosed in District residents in 2018. Eliminating water-holding containers that provide larval habitat for many vector species continues to prove an effective strategy for preventing mosquito-borne illnesses,

and in 2018 staff collected and recycled 9,730 tires. 2018 also saw eight cases of Jamestown Canyon illnesses in Minnesota with two occurring in District residents.
The District continued monitoring the distribution of ticks in the metro area. The average number of *I. scapularis* collected per mammal (1.50) in 2018 rebounded from our tabulation of 1.21 from 2017 and is our second highest tabulation to date. Our record high of 1.68 had been tabulated in 2016. However, they remain comparable to the averages we have come to expect since 2000. Preparations are underway for possible introductions of the longhorned tick into Minnesota.

Mosquito and Black Fly 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 acres treated in 2018 (189,191 acres) were slightly lower than in 2017 (195,061 acres). Analysis shows that cost savings efforts resulted in a reduction of 28,370 acres of potential larval treatments. A cumulative total of 263,360 catch basin treatments were made in three rounds to control WNV vectors. Adulticide treatments in 2018 (38,479 acres) were lower than 2017 levels when 41,908 acres were treated.

In our ongoing efforts to review program needs and effectiveness, MMCD staff evaluated control of spring *Aedes* species. Given very low numbers of adult mosquitoes found in the metro core, we increased the number of larvae required to trigger aerial treatments. However, we had concerns about possible spring *Aedes* transmission of Jamestown Canyon virus (also expressed in a TAB resolution last year), so we reinstated some treatments in areas with low human populations that had been dropped for cost savings in 2017. Spring *Aedes* populations remained low in 2018 in the most populated areas of the District.

To control black flies in the metro area, MMCD treated 28 small streams sites with *Bti* when the *Simulium venustum* larval population met the treatment threshold. MMCD also made 47 large river treatments with *Bti* when the larval population of the target species met the treatment threshold. Adult black fly populations increased from 2017 levels. Sampling to monitor larval populations of *S. venustum* for treatment thresholds in the MnDNR-permitted small streams was delayed from mid-April until May due to the April blizzard. Minnesota river *Bti* treatments were suspended due to the dangerous flood-level conditions from mid-June through July.

Product and Equipment Testing

Evaluation of products, equipment, and processes is an important part of our program. In 2018, both 8- and 5-lb/acre dosages of VectoBac® G *Bti* achieved good control of *Ae. vexans* in air sites. Natular® G (5-lb/acre) effectively controlled *Ae. vexans* in air and ground sites. We revised our efficacy evaluation procedure to dip sites at least three days after rain. Natular® G (9-lb/acre) did not control cattail mosquitoes. Initial tests of Sumilarv® 0.5 G did not effectively control mosquito larvae in junk yard containers

Data Management, Public Information, Sustainability, and New Technologies

This year marked three major steps for MMCD's operations and data/mapping system: we added real-time tracking for helicopter treatments, started web-based map editing, and explored the use of drones (unmanned aerial vehicles – UAVs). We expect to use drones for aerial photo collection and to help with larval mosquito surveillance in 2019, while we explore future options.

Public requests for adult mosquito treatment were similar in number to 2017 compared to the record high in 2016. The number of requests reached a single peak just prior to the 4th of July holiday and then declined, similar to the adult mosquito counts. Calls requesting site checks for larval mosquitoes decreased in 2018 to more typical levels. Staff made presentations on mosquito biology at 41 schools. Subscribers to our GovDelivery, Facebook, and Twitter notices continue to increase.

Sustainability efforts continued to expand and become an integral part of MMCD operations. Six of our seven facilities are signed up to receive electricity starting in 2019 from a "Sunscription" with US Solar solar gardens in a program that will also reduce our electricity cost. We have added more fuel-efficient vehicles to our fleet, added options for composting waste, and started new ways to involve all staff in developing a culture of sustainability.

In their 2018 meeting the TAB passed a resolution recommending that "MMCD review current developments regarding CRISPR-Cas9 and gene drive techniques being used in the control of mosquitoes and ticks". These and other new techniques have been discussed not only in scientific meetings but increasingly in public media as their potential is recognized. Field tests of some sterile male techniques have begun in other parts of the world where the need for disease control is high. At this time MMCD staff do not see an urgent need to explore this technology for local use, but will continue to monitor trials in other areas.

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Chapter 1 Mosquito Surveillance

2018 Highlights

- 24.8 inches of snow fell in April and a cooler than average March and April resulted in a late start to the season
- The spring *Aedes* brood was small and compressed into a short timeframe
- A large rain event on Memorial Day kicked off the summer floodwater *Aedes* season
- Major summer *Aedes* mosquito peak occurred on July 2
- *Cq. perturbans* peaked the same time as the summer *Aedes*, July 2
- A record 5,629 of *An. quadrimaculatus* were captured – twice as many as in 2017
- Identified 18,054 larval samples

2019 Plans

- Evaluate placement of CO_2 and gravid traps

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. MMCD uses a variety of surveillance strategies 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, amphibians, and even worms. Mosquitoes differ in their peak activity periods and in how strongly they are attracted to humans or trap baits (e.g., light, CO_2, or highly organic water), 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 and live on average two weeks. *Coquillettidia perturbans* (cattail mosquito) develops in cattail marshes. There is one emergence, which begins in early June, peaking around July 4. 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.

2018 Surveillance

Precipitation

Rainfall is a key factor for understanding floodwater mosquito populations and planning control efforts. Generally, rain amounts over one inch can induce a hatch of *Aedes* mosquitoes. For that reason, MMCD uses a network of rain gauges, read daily by staff or volunteers, to measure rainfall. The rainfall network was established over 50 years ago. These data were shared with the Minnesota State Climatologist's office for analysis, typically at the end of each month. Currently, the rain gauge data is entered 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 Center (RFC) creates 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). This dataset is one of the best sources of timely, high resolution precipitation information available.

Average seasonal rainfall in the District is calculated from May through September using historical MMCD rain data and CoCoRaHS gauges. This time period is referred to as the 'mosquito season'. April rainfall can influence adult emergence in May as well. The average rainfall for the weeks of April 29 through September 29, 2018 was 22.54 inches, which is 2.82 inches above the 59-year District average of 19.72 inches.

Figure 1.1 shows the weekly rainfall averages experienced from April – September 2018. Early April precipitation in 2018 came as snow. Nine inches fell on April 2-3 and then on April 14, blizzard warnings were posted and the Twin Cities received 15.8 inches of snow. Several brood-inducing rain events occurred from the end of May through early July. The two largest rain events occurred in June and September; the latter event occurred late in the month when many floodwater mosquito eggs are in diapause and do not hatch.

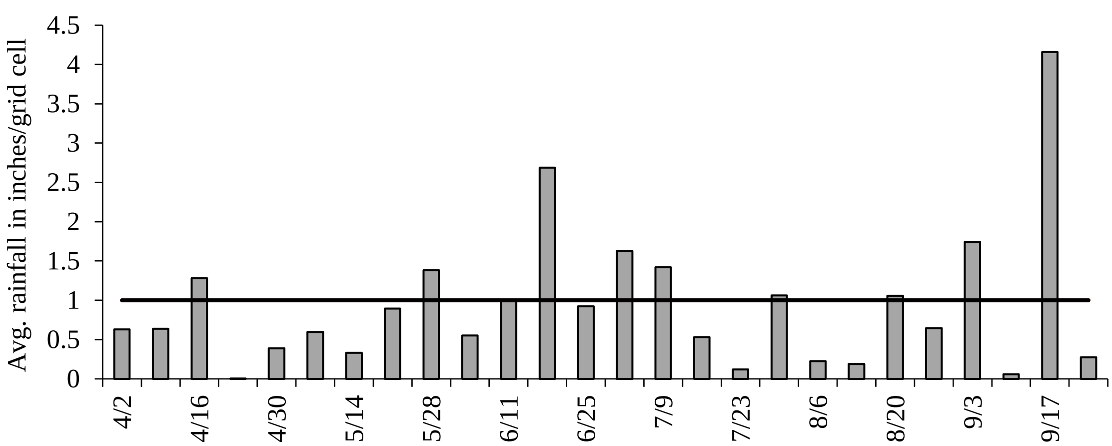


Figure 1.1 Weekly rainfall amounts per grid cell, 2018 (RFC data). Dates represent the Monday of each week. Solid line indicates 1-inch, the amount sufficient to induce egg-hatch.

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/spring of 2017-2018 was relatively cool, especially in February and April (Figure 1.2). April was about 11 degrees colder than normal. Ice-out did not occur until May 5 on Lake Minnetonka and was tied for latest ice-out date since 1857. Conditions warmed up in May and the first 100-degree day occurred on Memorial Day. The snowfall total for the season was 52.2 inches from November-March, which was typical for that time period. An additional 26.1 inches of snow fell within the first two weeks of April. The average snowfall for April is 2.5 inches. The first larval sample was taken on April 21, much later in the season than usual. June, July, and September had more rainfall than normal, while August was 2.4 inches below normal.

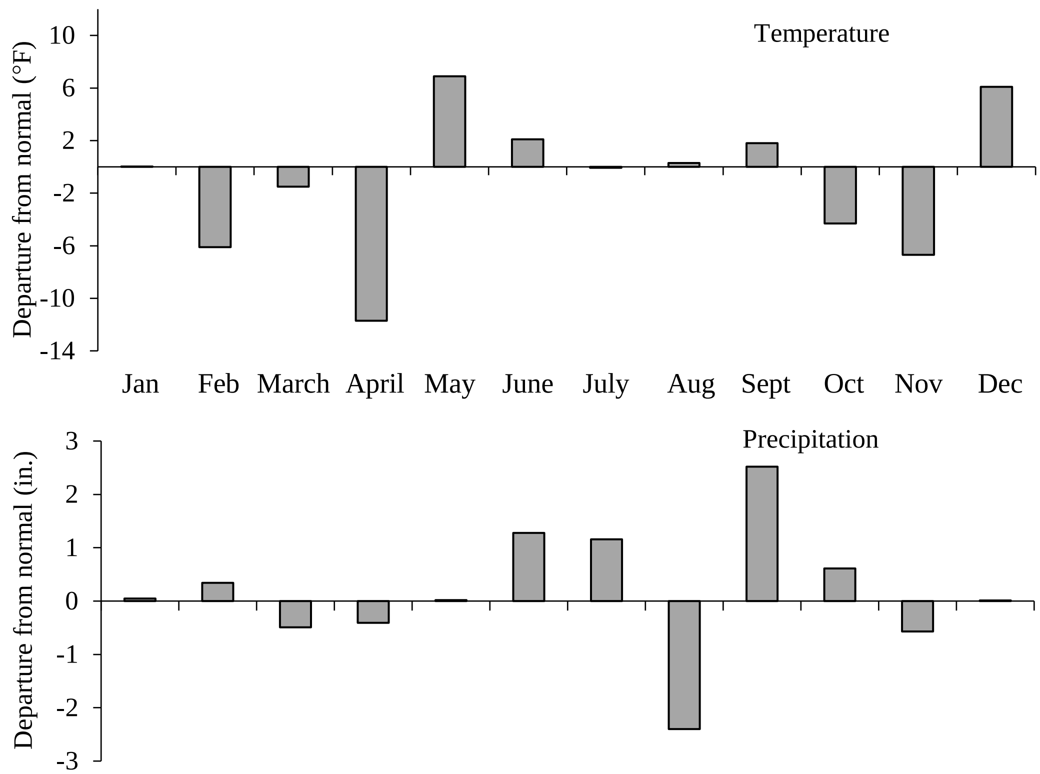


Figure 1.2 Monthly departures from normal for temperature and precipitation January-December, 2018 (source: National Weather Service, Twin Cities Station).

In addition to the spring *Aedes* brood, there were twelve summer rainfall events sufficient to produce summer *Aedes* broods – three large broods and nine small- to medium-sized broods; the amount of area affected by rainfall, the amount of rainfall received, and the resultant amount of mosquito production determines brood size. Figure 1.3 depicts the geographic distribution and magnitude of weekly rainfall received in the District from April through September 2018. Since some weeks had multiple rain events, the cumulative weekly rainfall does not identify individual rain events. Medium to dark gray shading indicates rainfall greater than or equal to one inch, sufficient to initiate a brood. The largest rain event of the year was widespread, but it occurred the week of September 16.

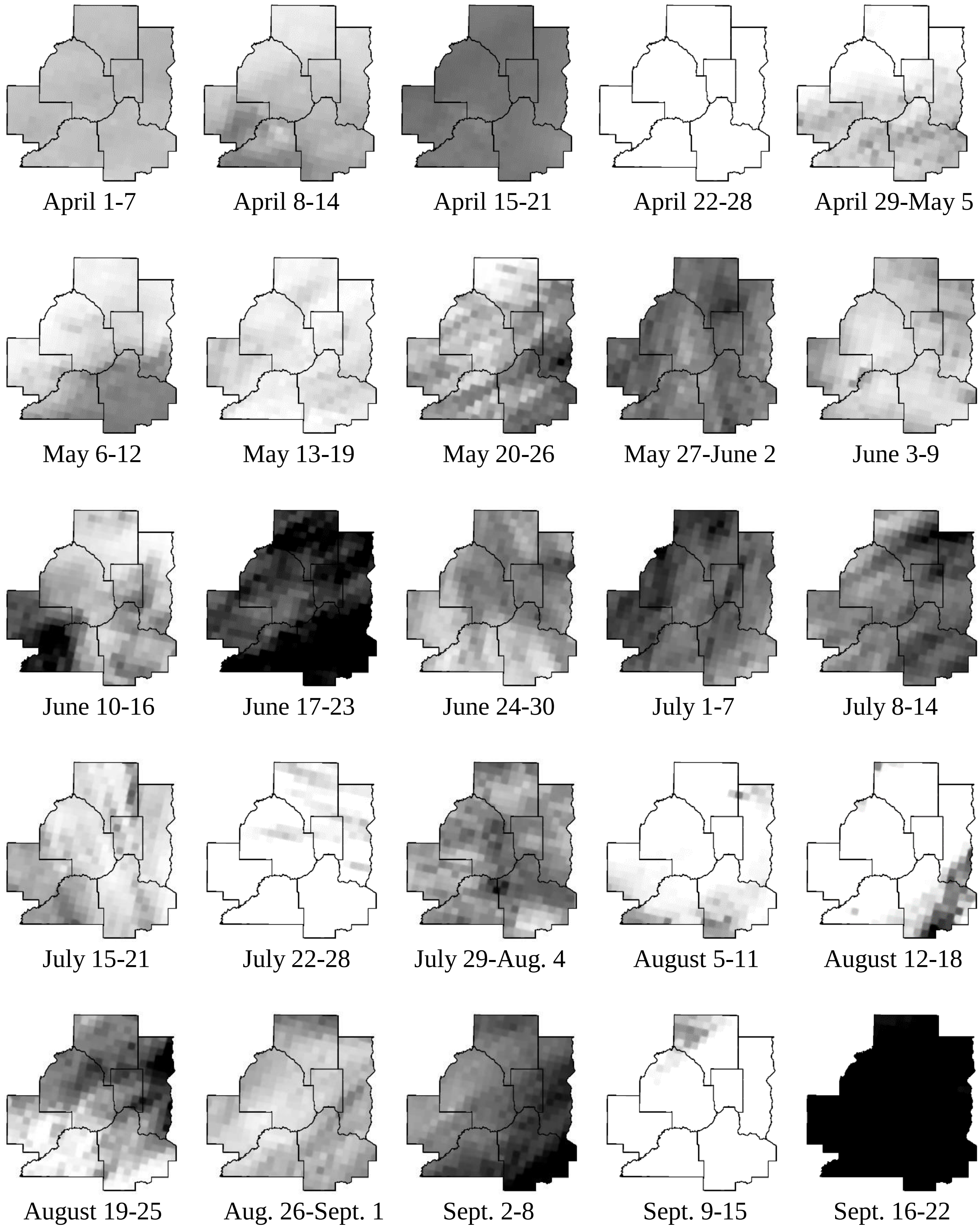
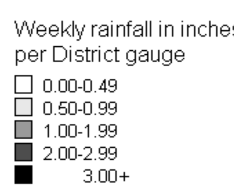


Figure 1.3 Weekly rainfall in inches, 2018. RFC-corrected data using 406 4x4 km grid cells. Inverse distance weighting was the interpolation method used for shading the maps.



Larval Collections

Larval mosquito inspections are conducted 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. japonicus,* and *Ae. albopictus*. 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 (air sites), larvae are identified to genus only; this year, however, spring *Aedes* were identified to species. *Culex* larvae are identified to species to differentiate vectors. Staff process lower priority samples as time permits and those are identified to species. In 2018, lab staff identified 18,054 larval samples (Figure 1.4).

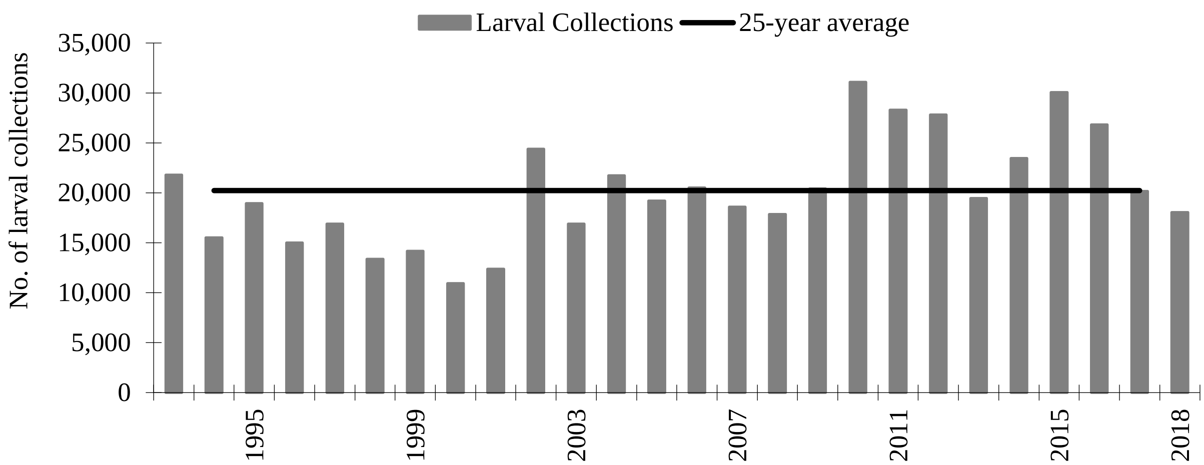


Figure 1.4 Yearly total larval collections, 1993-2018, and 25-year average. Prior to 2015, these totals did not include container samples.

The results of 9,593 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, and 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 47.3% of the samples. The next three in the top five are: *Ae. cinereus* (25.0%), *Culex territans* (15.9%), and *Cx. restuans* (13.0%), a West Nile virus (WNV) vector. *Aedes excrucians* (8.3%), a spring species, was number five. A higher number of species level identifications were done this year (especially in the North and East facilities) to investigate the possibility of Jamestown Canyon virus transmission by identifying the presence of possible vectors – this led to increased percentages of occurrence of some spring *Aedes* species (Table 1.1).

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, 2018; the total number of samples processed to species is in parentheses. A percent of total less than 0.1 is indicated by <. Unid* means unidentifiable to species.

	Percent of samples where species occurred by facility							
Species	North (1,376)	East (2,299)	South Rosemount (1,519)	South Jordan (1,539)	West Plymouth (974)	West Maple Grove (525)	Wetland Total (8,232)	Structures Total (1,361)
Aedes abserratus	4.5	1.6	0.5	0.1	0.4	1.0	1.4	
aurifer	<						<	
canadensis	0.6	0.5	1.1	1.6	0.3	0.2	0.8	
cinereus	48.8	20.8	6.3	18.3	31.1	43.8	25.0	<
communis								
dorsalis	<		<	0.1	0.4	0.6	0.1	
euedes	<						<	
excrucians	23.8	5.6	0.7	0.9	5.1	15.6	7.5	
fitchii	5.0	1.0	<	<	0.3	2.1	1.3	
hendersoni				<			<	<
implicatus	1.3	0.6	<	<	1.0	0.8	0.6	
intrudens	<						<	
japonicus	0.2	0.5	0.6	0.7	0.5	0.2	0.5	11.9
nigromaculis	<						<	
punctor	2.5	1.3	<	<	0.9	0.6	1.0	
riparius	2.3	1.2	0.3	0.5	2.4	3.2	1.3	
spencerii								
sticticus	1.5	0.9	0.8	0.7	0.4	4.0	1.1	
stimulans	5.6	5.3	1.5	4.0	5.5	15.2	5.1	
provocans	2.0	0.3				0.4	0.4	
triseriatus	<			0.2	0.1		<	2.9
trivittatus	2.5	2.8	14.9	9.4	1.8	1.1	6.0	<
vexans	40.8	37.9	65.9	56.8	45.1	28.4	47.3	9.1
Ae. species unid*	27.0	23.6	24.2	15.1	12.5	28.2	21.7	6.8
Anopheles earlei								
punctipennis	0.7	0.4	0.4	0.6	1.3	0.2	0.6	1.1
quadrimaculatus	1.3	1.0	0.1	1.4	0.8	0.6	0.9	
walkeri				<			<	
An. species unid	2.5	3.8	1.4	3.9	3.0	1.3	2.9	2.5
Culex erraticus								
pipiens	3.1	4.1	5.5	3.4	8.4	2.9	4.5	52.4
restuans	9.9	12.0	16.7	13.6	16.9	6.5	13.0	67.2
salinarius		0.1		<	0.1		<	0.1
tarsalis	0.4	0.5	0.8	1.2	1.6	1.0	0.9	1.1
territans	9.2	28.1	9.2	16.4	12.1	4.4	15.9	9.5
Cx. species unid	3.1	3.3	4.7	5.1	6.0	1.5	4.0	50.0
Culiseta inornata	0.1	1.8	1.8	2.7	3.6	2.5	1.9	0.9
melanura								
minnesotae	0.9	2.5	0.1	0.5	0.9		1.1	
morsitans	<	0.2					<	
Cs. species unid	2.4	6.3	0.7	1.4	2.0	1.5	2.9	
Or. signifera								
Ps. ciliata								
columbiae								
ferox	0.3	0.3	0.5	0.5	0.3		0.4	
horrida			0.1				<	
Ps. species unid	<	1.0	1.6	0.8	0.4		0.8	
Ur. sapphirina	0.5	1.0	0.4	1.4	0.5	0.4	0.8	<

Adult Mosquito Collections

The District employs a variety of surveillance strategies to collect adult mosquitoes which utilize different behaviors inherent to 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 (i.e., attracted to light) 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 a liquid, olfactory 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*, and *Ae. albopictus*). The information obtained from sampling is used to direct control activities and to monitor vector populations and disease activity. Mosquitoes that vector pathogens that cause disease are discussed in Chapter 2: Vector-borne Disease.

Monday Night Network The sweep net and CO_2 trap data reported here are weekly collections referred to as the 'Monday night network'. Staff make two-minute sweep net collections at a prescribed time at their homes on Monday evenings to monitor mosquito annoyance experienced by citizens. In addition, CO_2 traps are set up in natural areas such as parks or wood lots to monitor overall mosquito abundance. To achieve a District-wide distribution of CO_2 traps, some employees set traps in their yards as well. Figure 1.5 shows the sweep net and CO_2 trap locations and their uses [i.e., general monitoring, virus testing, and eastern equine encephalitis (EEE) vector monitoring]. Although a few locations are located beyond District boundaries, only data from locations within are included in the analysis. Sweep net collections and CO_2 traps were operated once weekly for 20 weeks, May 7 - September 17.

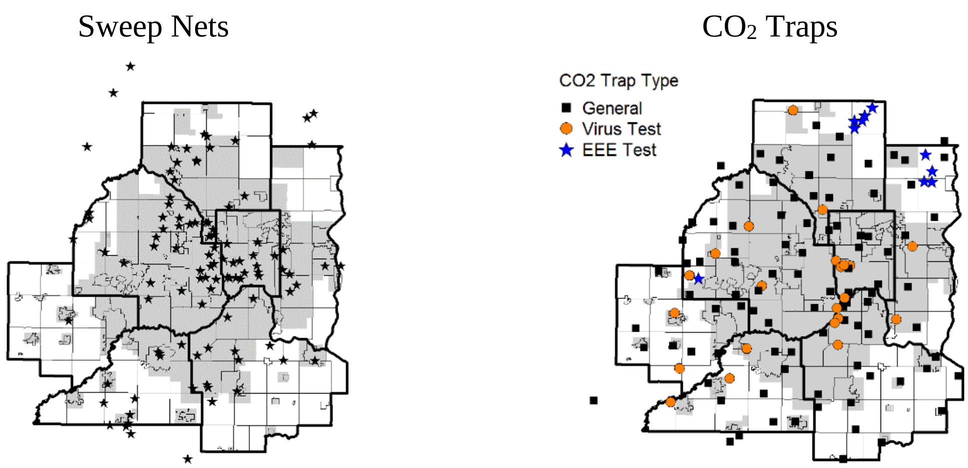


Figure 1.5 Locations of weekly sweep net and CO_2 traps used to monitor general mosquito populations and disease vectors (virus test and EEE test), 2018.

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. absserratus/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, are also attracted to mammals; this species is important in the transmission of WNV to humans and is best captured in CO_2 traps.

Sweep Net The District uses weekly 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 37-73 per evening. The treatment threshold for sweep net sampling is two mosquitoes per two-minute sweep.

Staff made 1,159 collections containing 2,210 mosquitoes in 2018. The average number of summer *Aedes* collected in the evening sweep net collections in 2018 was almost twice as much as last year but still below the 18-year average (Table 1.2). *Coquillettidia perturbans* levels were also below the 18-yr average as were the spring *Aedes*. *Culex tarsalis*, which are infrequently collected in sweep net samples, were near average.

Table 1.2 Average number of mosquitoes collected per evening sweep net collection within the District, 2014-2018 and 18-year average, 2000-2017 (± 1 SE).

Year	Summer *Aedes*	*Cq. perturbans*	Spring *Aedes*	*Cx. tarsalis*
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
2017	0.79	0.49	0.01	0.001
2018	1.50	0.22	0.03	0.009
18-yr Avg.	1.77 (±0.32)	0.34 (±0.05)	0.11 (±0.03)	0.009 (±0.002)

CO_2 Trap CO_2 traps baited with dry ice are used to monitor host-seeking mosquitoes and the presence and abundance of species that transmit pathogens that cause human disease. The standard placement for these traps is approximately 5 feet above the ground, the height at which *Aedes* mosquitoes typically fly. Some locations have elevated traps which are placed approximately 25 feet high in the tree canopy to monitor bird biting species (i.e., *Culex* spp.). The treatment threshold is 130 mosquitoes per CO_2 trap (5 per trap for *Culex* vector species).

In 2018, we placed 130 traps at 118 locations (twelve of these locations have low traps paired with elevated traps) to allow maximum coverage of the District (Figure 1.5). An additional seven traps were located outside District boundaries, at employee homes, and were not included in these analyses. The “General” trap type locations are used to monitor non-vector mosquitoes. There are 44 traps designated as “Virus Test; all *Culex* specimens collected from these traps are tested for WNV (Figure 1.5). 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 species populations and to obtain specimens for EEE testing (Figure 1.5, “EEE Test” trap type).

A total of 2,254 District low CO_2 trap collections taken contained 497,925 mosquitoes in 2018. The total number of these traps operated weekly varied from 108-117. The average number of mosquitoes detected in CO_2 traps is found in Table 1.3. As is typical, *Ae. vexans* was the predominant species in the District. Populations levels were higher than last year, but still below the 18-year average. *Coquillettidia perturbans* populations were normal and well below the high levels detected in 2017. Captures of spring *Aedes* increased in 2018 but remained below the long-term average. *Culex tarsalis* numbers were less than half the average. This was the fourth consecutive year that *Cx. tarsalis* numbers were well below the District's 18-year average. More in-depth discussion of *Cx. tarsalis* is found in Chapter 2: Mosquito-borne Disease.

Table 1.3 Average numbers of mosquitoes collected in CO_2 traps within the District, 2014-2018 and 18-year average, 2000-2017 (± 1 SE).

Year	Summer *Aedes*	*Cq. perturbans*	Spring *Aedes*	*Cx. tarsalis*
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
2017	134.8	140.8	2.5	0.6
2018	153.4	52.6	5.3	0.8
18-yr Avg.	209.2 (±30.3)	52.9 (±8.1)	8.0 (±2.0)	1.9 (±0.3)

Geographic Distribution The weekly District 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, respectively. The computer-assisted interpolations of mosquito abundance portray the predicted abundance of mosquitoes at locations without CO_2 traps. Therefore, some dark areas are the result of single collections without another trap in close proximity and may not reflect actual densities of mosquitoes.

Spring *Aedes* populations were detected from May 29 – July 2 and were mostly confined to a few locations on the outer edges of the District or in localized areas (Figure 1.6). There were a few locations that had higher, concentrated levels of spring *Aedes* – mostly in northern and eastern Anoka County.

The first detections of summer *Aedes* occurred the third week of May. Populations steadily increased and were collected at above threshold levels (≥130 mosquitoes/trap night) in some scattered locations throughout the season (Figure 1.7). Heavy population levels were detected in Scott and Carver counties on June 25. Widespread and very high levels were detected July 2 – the highest of the season. A large rain event the week of June 17 was the cause of this intense infestation.

The single generation of *Cq. perturbans* was first detected on June 4 (Figure 1.8). Higher levels were detected beginning June 18. The highest levels were detected July 2, which is typical for this species. Populations were detected into the third week of August. Highest levels occurred in their usual hot spots in the northern District borders and in untreated (priority zone 2) areas.

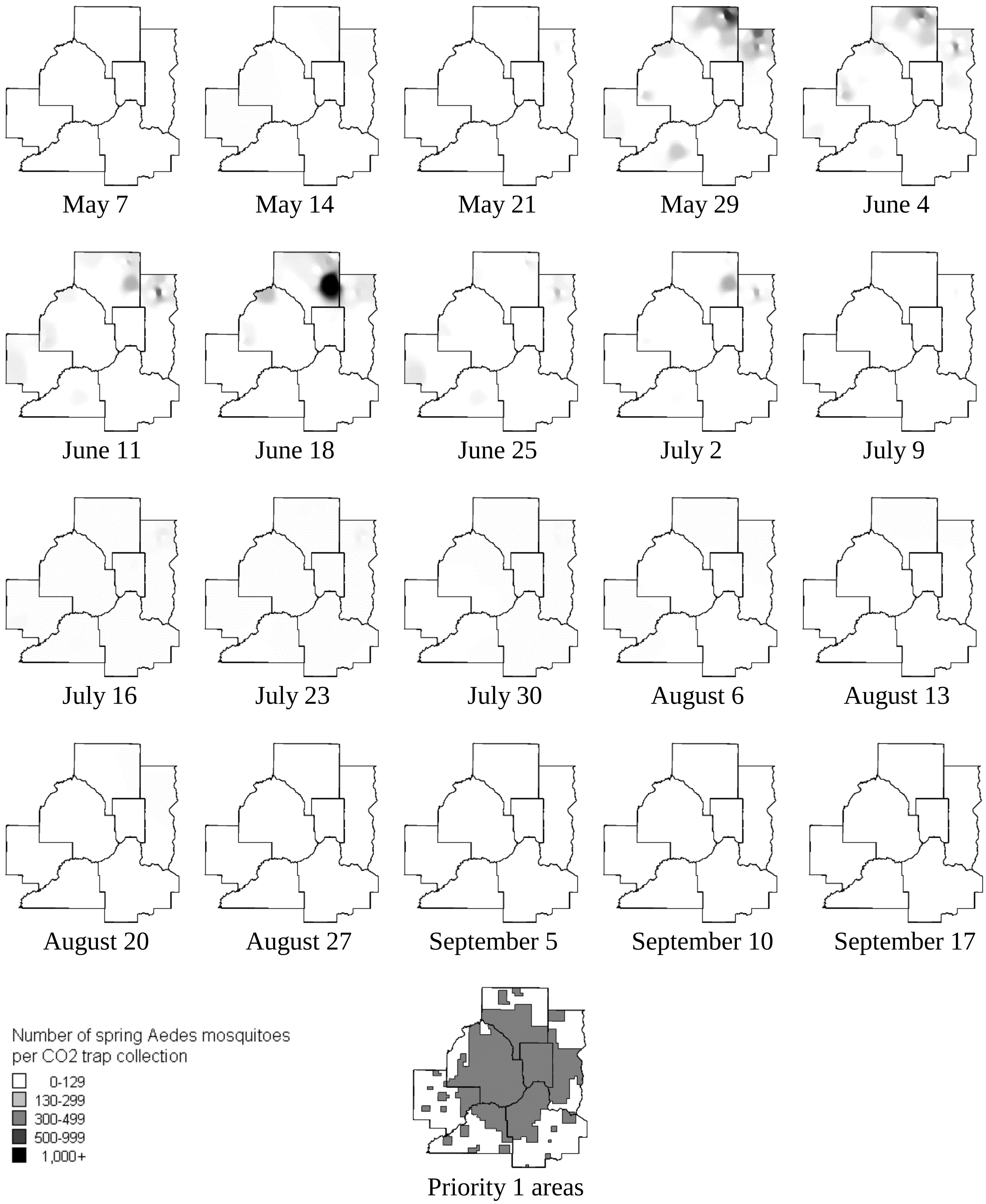


Figure 1.6 Number of spring *Aedes* in District low (5 ft) CO_2 trap collections, 2018. The number of traps operated per night varied from 108-117. Inverse distance weighting was the interpolation method used for shading the maps. Treatment threshold is >130 mosquitoes/trap night. Priority 1 shaded area map for reference.

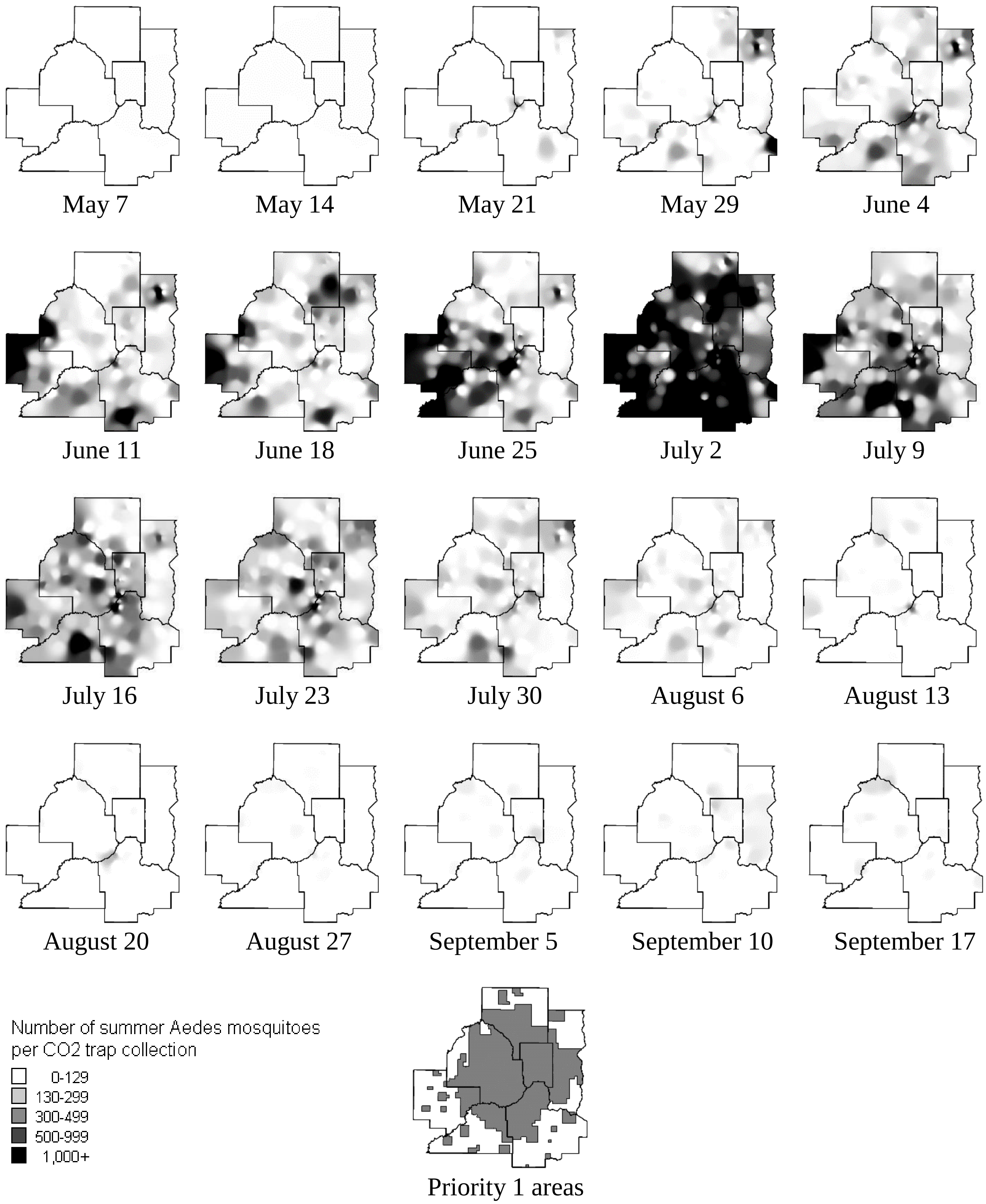


Figure 1.7 Number of summer *Aedes* in District low (5 ft) CO_2 trap collections, 2018. The number of traps operated per night varied from 108-117. Inverse distance weighting was the interpolation method used for shading the maps. Treatment threshold is >130 mosquitoes/trap night. Priority 1shaded area map for reference.

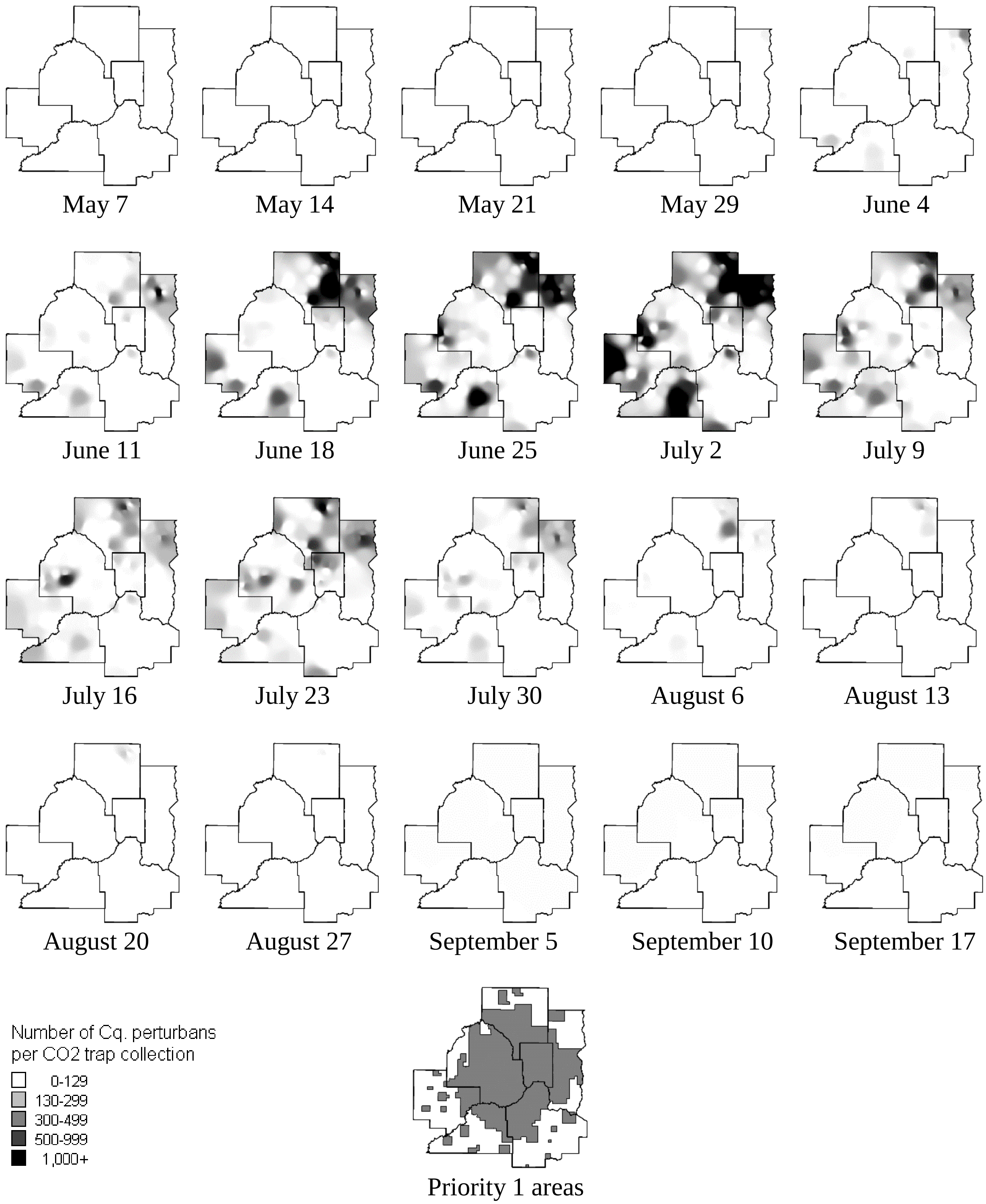


Figure 1.8 Number of *Cq. perturbans* in District low (5 ft) CO_2 trap collections, 2018. The number of traps operated per night varied from 108-117. Inverse distance weighting was the interpolation method used for shading the maps. Treatment threshold is >130 mosquitoes/trap night. Priority 1 shaded area map for reference.

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. If rain or cold temperatures are forecasted on sampling night, surveillance is postponed until the next night. Figure 1.9 depicts the actual temperature at 9 p.m. on the scheduled sampling night. In 2018, sampling with CO_2 traps and sweep nets started May 7. Only a few nights were cool, but still warmer than the flight minimum. The MN DNR reported that 2018 had the second highest, behind 2010, overnight temperatures (http://climateapps.dnr.state.mn.us/index.htm). Sampling continued as scheduled.

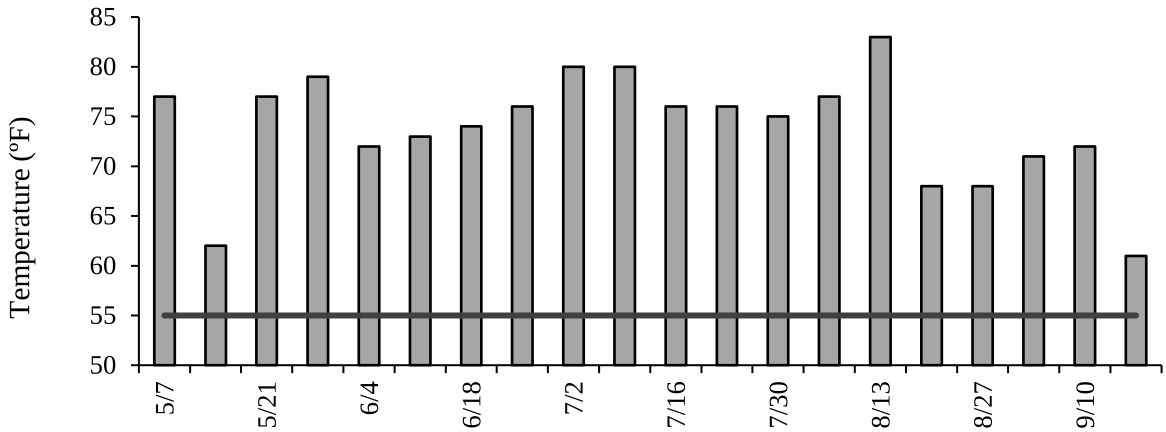


Figure 1.9 Temperature at 9:00 PM on actual dates of Monday night surveillance, 2018 (source: National Weather Service, Twin Cities Station). The black horizonal line indicates the mosquito flight threshold, 55 °F.

Figures 1.10 and 1.11 show the seasonal distribution of the three major groups of mosquitoes from early May through mid-September, detected by sweep netting and CO_2 traps. Adult spring *Aedes* were first detected May 21 and peaked on May 29. The sweep net and CO_2 traps both detected this peak at the same time. Another peak was detected on June 18. Both of those peaks were similar to the 18-year average. Populations diminished by mid-July.

Summer *Aedes* were first detected in sweep nets on June 4 and on May 21 in CO_2 traps. Populations steadily increased with the highest numbers of summer *Aedes* detected on July 2, well above the 18-year average. Mosquitoes continued to be at or below average levels until sampling ended in September.

The single generation *Coquillettidia perturbans* was initially detected June 4 for both the sweep net and CO_2 trap sampling. Emergence continued from that point and peaked on July 2, its typical time. Captures remained close to average throughout the season with the final detection during the third week of August.

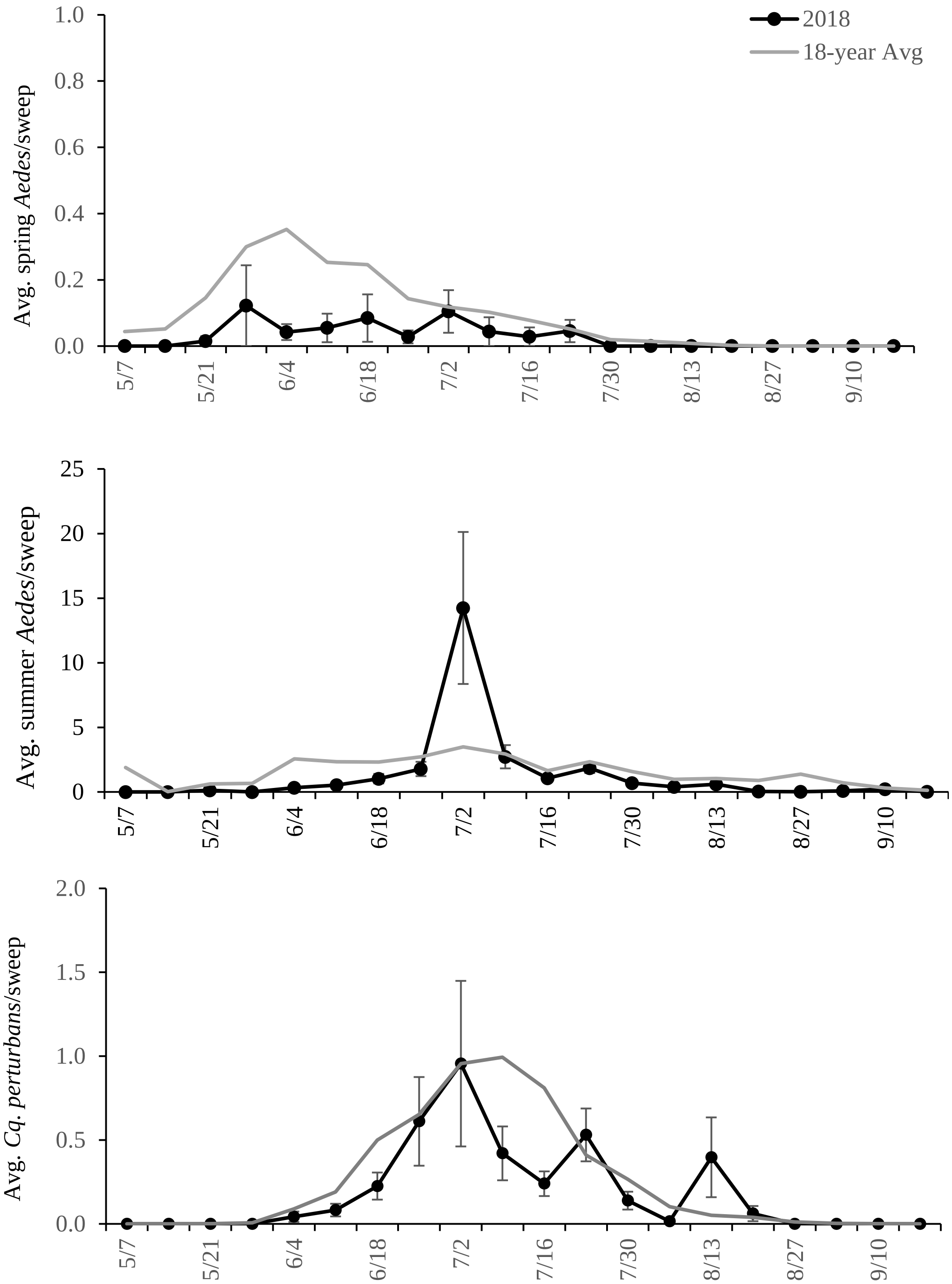


Figure 1.10 Average number of spring *Aedes*, summer *Aedes*, and *Cq. perturbans* per sweep net collection, 2018 vs. 18-year average. Dates are the Mondays of each week. Error bars equal <u>+</u> 1 standard error of the mean.

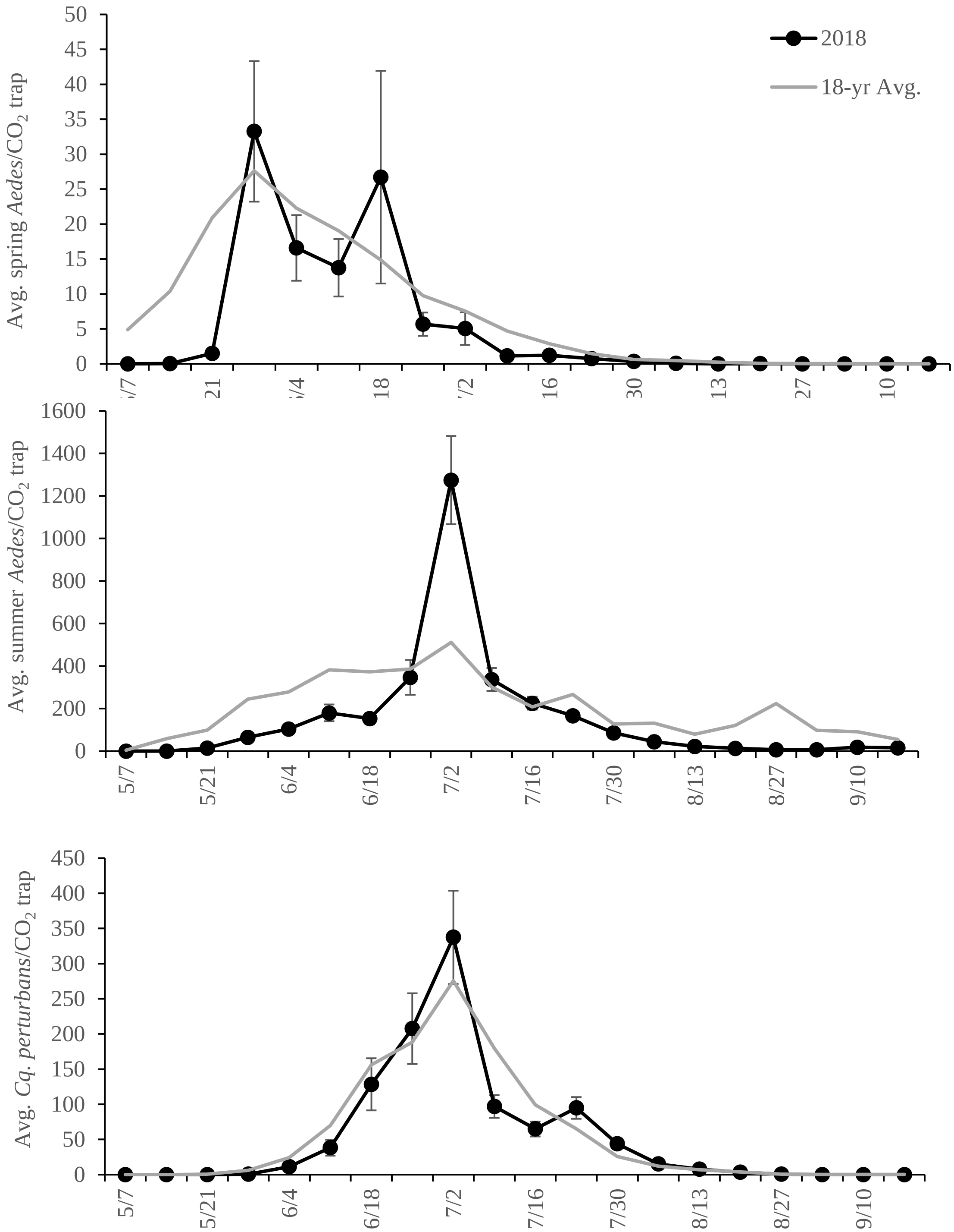


Figure 1.11 Average number of spring *Aedes*, summer *Aedes*, and *Cq. perturbans* per CO_2 trap, 2018 vs. 18-year average. Dates are the Mondays of each week. Error bars equal ± 1 standard error of the mean.

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.

In 2018, we reduced the trapping locations to only include those sites that were productive and that have been operating for twenty years or more. Three locations were eliminated: Trap SF, Trap AV, and Trap MN. The State Fair (SF) location was eliminated because it already had ample surveillance (i.e., two CO_2 traps there) and this location was far away from the original St. Paul trap site. The trap at the Minnesota Zoo in Apple Valley (AV) was moved one half mile to a new location within the zoo in 2017; we eliminated this location due to low capture rates. The Minnetrista (MN) trap was also discontinued in 2018 because it was set up relatively recently in 2009. The remaining four traps are in the following locations: Trap 9 in Lake Elmo, Trap 13 in Jordan, Trap 16 in Lino Lakes, and Trap CA1 in the Carlos Avery State Wildlife Management Area (Figure 1.12). Traps 9 and 16 have operated from 1965-2018. The CA1 trap started in 1991. Trap 13 has been at MMCD's Jordan Office location since 1998.

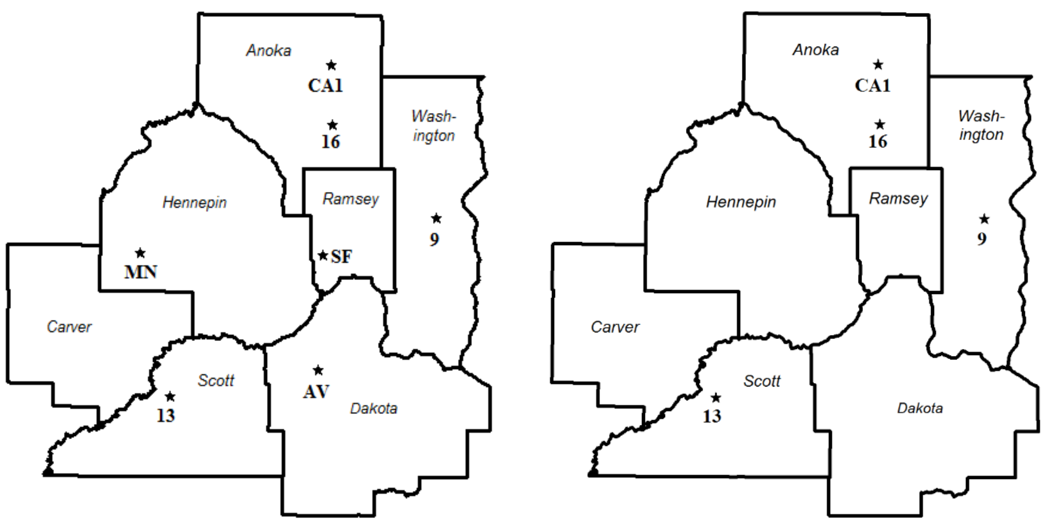


Figure 1.12 NJ light trap locations, 2016 vs. 2018.

Trapping occurs nightly for 20 weeks from May through September and staff identify all adult female mosquitoes to species. A comparison of the major species collected from those four traps is shown in Appendix B.

The top five most abundant species collected were *Ae. vexans* (48% of all female mosquitoes captured), *Cq. perturbans* (36%), *Anopheles quadrimaculatus* (4%), *Ae. abserratus/punctor* (3% including *Ae. abserratus, Ae. punctor,* and unidentifiable *abserratus/punctor*), and *Ae. cinereus*

(2%) (Table 1.4). The Carlos Avery trap (CA1) collected the 63% of all females collected followed by Lino Lakes (Trap 16, 18.8%), Lake Elmo (Trap 9, 10.9%), and Jordan (Trap 13, 6.8%).

Aedes vexans occurred most frequently in the CA1 and Trap 16 traps. *Coquillettidia perturbans* was most abundant in the CA1 trap (90% of all *Cq. perturbans* collected). *Anopheles quadrimaculatus* was found in highest numbers in Trap 9 and accounted for 63% of all specimens captured. The spring *Aedes* species of *Ae. absserratus* and *Ae. punctor* were also most abundant in CA1. Ninety-seven percent of all *Ae. cinereus* were collected in the CA1 trap.

Trap 9, located in Washington County, was dominated by *Aedes vexans*. *Anopheles quadrimaculatus* and *Cq. perturbans* were the next most abundant species. Of the four NJ trap locations, this location also captured the most *Ae. japonicus* (13 of 15).

Trap 13 is located in Scott County. The trapping location is adjacent to a river floodplain with nearby cropland in a rural landscape. The most abundant species collected were *Ae. vexans*, *An. quadrimaculatus*, and *Ae. trivittatus* (a river floodplain species).

Trap 16 is located in southeastern Anoka County. The most abundant species collected in this trap were *Ae. vexans* and *Cq. perturbans*. The next most abundant species collected was *Cs. minnesotae*. This area is inside the District's treatment area.

The Carlos Avery trap (CA1) is located in the northern part of the District in Anoka County and has a variety of mosquito habitats including ephemeral spring woodland pools, cattail marshes, and many other types of habitats from permanent to temporary marshes and spruce-tamarack bogs. Consequently, this location has a diverse mosquito fauna. The CA1 trap was dominated by *Cq. perturbans*, *Ae. vexans*, *Ae. cinereus*, the spring species *Aedes abserratus* and *Aedes punctor*, in order of rank abundance. Also abundant were three *Anopheles* species: *An. punctipennis*, *An. quadrimaculatus*, and *An. walkeri*. Twice as many *An. walkeri* were captured as the former two *Anopheles* species. *Culiseta minnesotae* was also abundant and comprised 93% of the *Culiseta* captured. This location does not receive any mosquito control.

Table 1.4 Total numbers and frequency of occurrence for each species collected in New Jersey light traps, May 5 - September 21, 2018.

	Trap Code, Location, and Number of Collections				Summary Statistics		
	9	13	16	CA1			
	Lake	Jordan	Lino	Carlos	Total		
	Elmo		Lakes	Avery	Collected	% Female	Avg per
Species	136	140	100	125	501	Total	Night
Ae. abserratus	0	0	0	106	106	0.50%	0.21
atropalpus	0	0	0	0	0	0.00%	0.00
aurifer	0	0	0	0	0	0.00%	0.00
canadensis	0	0	0	4	4	0.02%	0.01
cinereus	1	2	12	438	453	2.12%	0.90
dorsalis	0	1	0	0	1	0.00%	0.00
excrucians	1	0	0	1	2	0.01%	0.00
fitchii	0	0	0	0	0	0.00%	0.00
hendersoni	0	0	0	0	0	0.00%	0.00
implicatus	0	0	0	0	0	0.00%	0.00
japonicus	13	0	0	2	15	0.07%	0.03
nigromaculus	0	0	0	0	0	0.00%	0.00
punctor	0	0	1	52	53	0.25%	0.11
riparius	0	0	0	1	1	0.00%	0.00
spencerii	0	0	0	0	0	0.00%	0.00
sticticus	12	57	0	11	80	0.38%	0.16
stimulans	0	0	0	1	1	0.00%	0.00
provocans	0	0	0	0	0	0.00%	0.00
triseriatus	2	1	0	1	4	0.02%	0.01
trivittatus	31	54	11	11	107	0.50%	0.21
vexans	1,283	856	3,581	4,468	10,188	47.76%	20.34
abserratus/punctor	0	0	3	510	513	2.40%	1.02
Aedes unidentifiable	8	1	8	66	83	0.39%	0.17
Spring *Aedes* unident.	1	1	0	12	14	0.07%	0.03
Summer *Aedes* unident.	14	21	3	4	42	0.20%	0.08
An. barberi	0	0	0	0	0	0.00%	0.00
earlei	0	0	0	0	0	0.00%	0.00
punctipennis	17	23	3	114	157	0.74%	0.31
quadrimaculatus	548	211	3	113	875	4.10%	1.75
walkeri	13	8	3	201	225	1.05%	0.45
An. unidentifiable	10	3	2	23	38	0.18%	0.08
Cx. erraticus	0	0	0	0	0	0.00%	0.00
pipiens	1	0	1	0	2	0.01%	0.00
restuans	9	7	12	46	74	0.35%	0.15
salinarius	1	0	0	0	1	0.00%	0.00
tarsalis	5	8	6	7	26	0.12%	0.05
territans	7	5	6	51	69	0.32%	0.14
Cx. unidentifiable	6	2	8	9	25	0.12%	0.05
Cx. pipiens/restuans	48	15	18	53	134	0.63%	0.27
Cs. inornata	0	0	0	0	0	0.00%	0.00
melanura	0	0	0	0	0	0.00%	0.00
minnesotae	6	12	43	153	214	1.00%	0.43
morsitans	1	0	1	10	12	0.06%	0.02
Cs. unidentifiable	0	0	0	1	1	0.00%	0.00
Cq. perturbans	269	163	274	7,027	7,733	36.25%	15.44
Or. signifera	0	0	0	0	0	0.00%	0.00
Ps. ferox	0	0	0	0	0	0.00%	0.00
horrida	2	0	0	0	2	0.01%	0.00
Ps. unidentifiable	0	0	0	0	0	0.00%	0.00
Ur. sapphirina	14	4	6	3	27	0.13%	0.05
Unidentifiable	4	6	14	26	50	0.23%	0.10
Female Total	2,327	1,461	4,019	13,525	21,332	100.00%	42.58
Male Total	1,342	454	760	4,125	6,681		
Grand Total	3,669	1,915	4,779	17,650	28,013		

Coquillettidia perturbans **Population Prediction**

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, 2012, and 2017) following years with higher than normal rainfall amounts (Figure 1.13). Analyses created by Dr. Roger Moon (University of MN) in 2016 showed the change in average *Cq. perturbans* levels from a given year to the next was related to the number of adults collected and average weekly total rainfall in the previous year. The predicted catch rate in 2018 was 66.7 *Cq. perturbans* per CO_2 trap, but the actual rate was 52.6 (Figure 1.13). The predicted amount of *Cq. perturbans* per CO_2 trap in 2019 is 57.1.

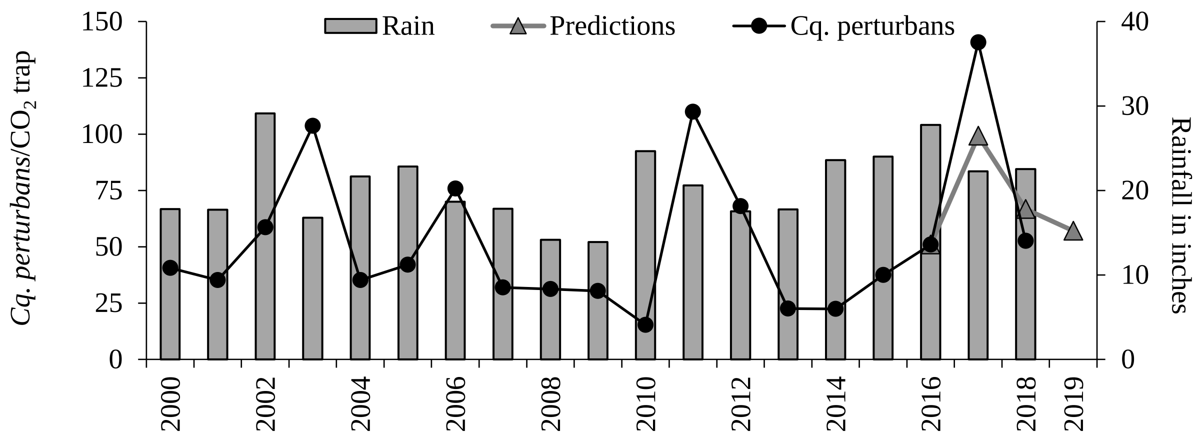


Figure 1.13 Average number of *Coquillettidia perturbans* in CO_2 traps and average seasonal rainfall per gauge, 2000-2018. The gray line shows the predicted amounts for 2017, 2018, and 2019.

Retroactively fitting the model created using the entire 2000-2018 dataset shows that this simple model which includes only the previous years' precipitation and average number of *Cq. perturbans* explains ~80% of the variation in the average abundance collected in CO_2 traps the following year (Figure 1.14).

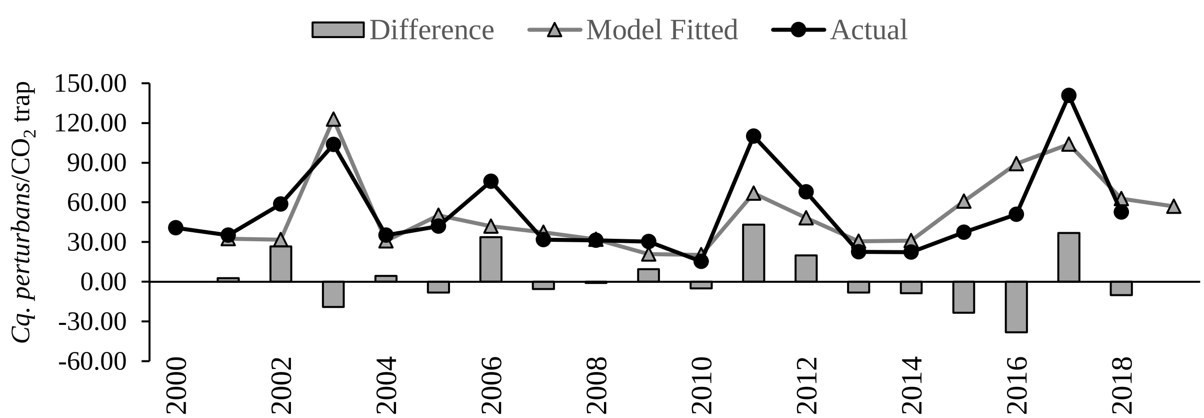


Figure 1.14 Difference between fitted model and actual *Cq. perturbans* counts per CO_2 trap.

Rare Detections

With our Monday Night Network, we monitor other species which are considered uncommon or rare in Minnesota. *Culex erraticus, Anopheles quadrimaculatus* and *Psorophora* species are discussed and have had noted increased populations in recent years.

Culex erraticus is rare in the District and only four were collected in 2018. It is a southern species with its northernmost distribution extending from the East Coast to Ohio, Indiana, Illinois, and parts of Iowa, Minnesota, and South Dakota (Darsie and Ward, 2005). Barr (1958) reported that the University of Minnesota insect collection had 45 specimens from two light trapping efforts in Wabasha, MN in 1939 and 1941. Larvae were detected in District sampling in 1961 and the first adults were detected in NJ light traps in 1988. Since that time low, sporadic numbers of adults have been detected until 2012 when 649 were collected in District CO_2 traps (Figure 1.15). During 2012, larvae were collected from six sites in Scott and Washington counties for the first time since the one Washington County sample in 1961. No larval samples have since been collected. Very few have been collected since 2012 – the yearly total collected ranges from three to 21 during 2013-2018.

A review of mosquito surveillance (NJ traps) records at Iowa State University (https://mosquito.ent.iastate.edu/browse_species2.php?spcID=373) beginning in 1969 show 2007 as the first occurrence of *Cx. erraticus* in Iowa (77 specimens taken). In addition, a separate study in Black Hawk County, Iowa collected 350 *Cx. erraticus* in 2006 using CO_2 traps from 12 sites and 292 total trap nights (Larson, 2018, pers. comm.). High levels have been detected since 2010. Interestingly, the very high populations we detected in 2012 did not occur in Iowa at the same time. Because *Cx. erraticus* is usually very 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.

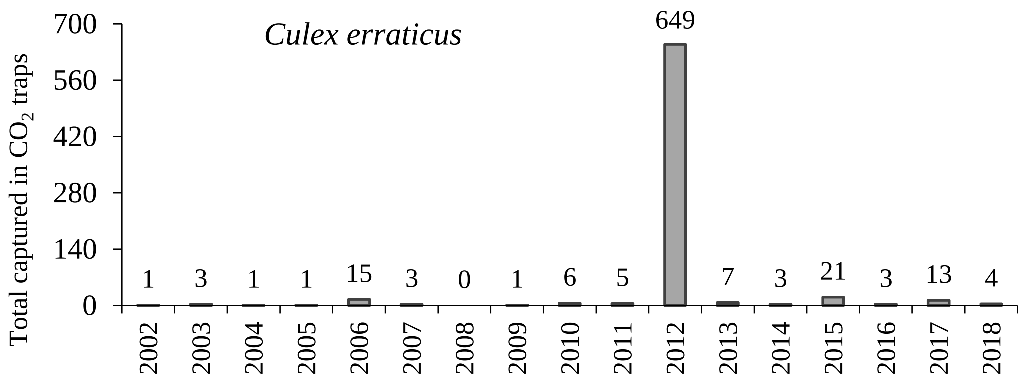


Figure 1.15 Total yearly *Culex erraticus* collected from Monday night CO_2 traps (low, high and any outside District), 2002-2018.

Anopheles quadrimaculatus is notable because it is a WNV maintenance vector and capable of transmitting dog heartworm and malaria. Historically, it was considered rare, but since the mid-2000s, it has occurred in traps more frequently (Figure 1.16). The reason for this is unknown but may be an indication of a range expansion. In Iowa this species has been on the rise since the 1990s (https://mosquito.ent.iastate.edu/browse_species2.php?spcID=370).

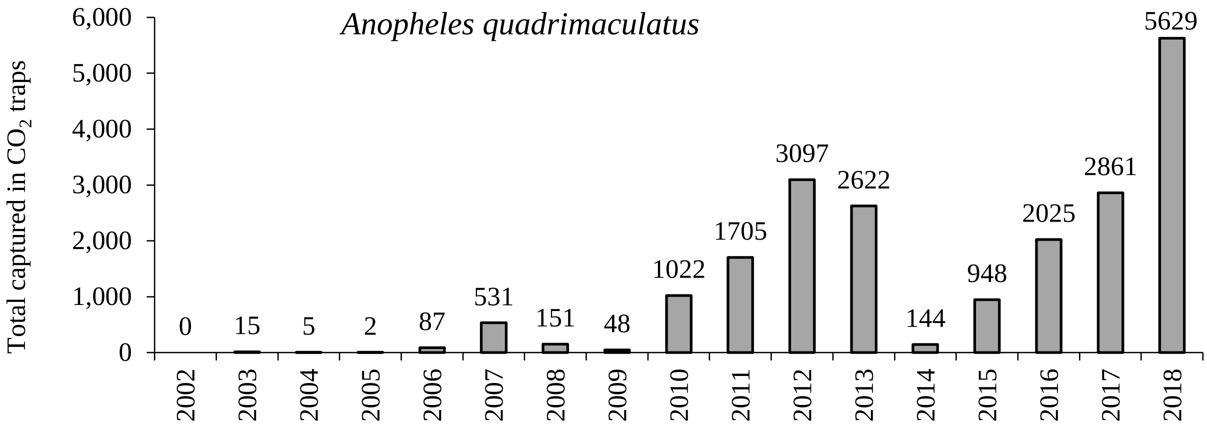


Figure 1.16 Total yearly *An. quadrimaculatus* collected from Monday Night CO_2 traps (low, high and any outside District), 2002-2018.

Psorophora species are human-biting floodwater mosquitoes that were considered 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 2008: *Ps. ferox* and *Ps. horrida* (Figure 1.17). Specimens that are missing the taxonomic characters needed for identification to species are recorded as *Ps.* species but are likely either *Ps. ferox* or *Ps. horrida*.

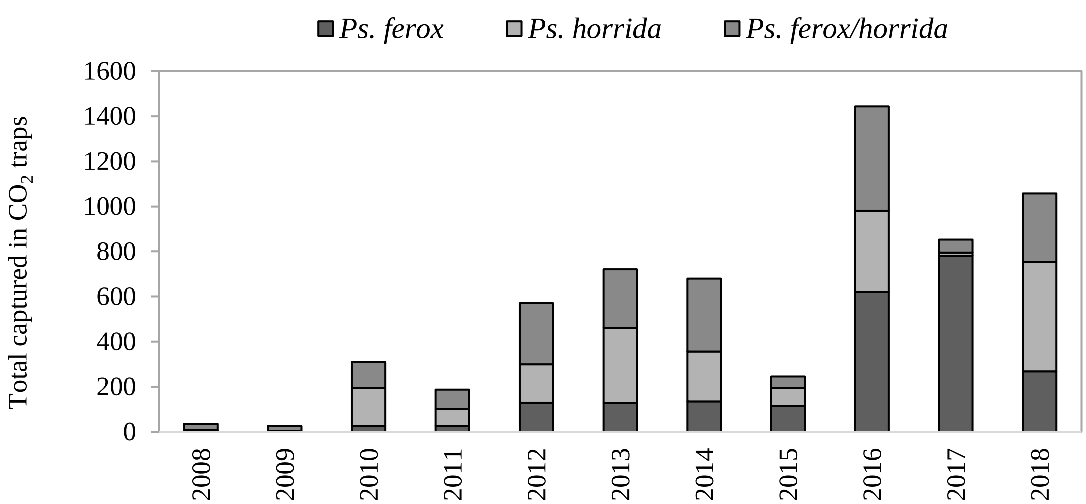


Figure 1.17 Total yearly *Ps. ferox*, *Ps. horrida* and *Ps. ferox/horrida* collected from Monday Night CO_2 traps (low, high and any outside District), 2008-2018.

Several viruses have been isolated from *Ps. ferox* (and other species in the genus *Psorophora*), but this species is generally not thought to play a major role in pathogen transmission to humans. In other parts of the country, *Psorophora* are known to frequently and voraciously bite people, but only nine *Psorophora* were identified in 17 years of Monday night sweep net collections. Southeastern Minnesota is on the northern edge of their North American ranges; it appears that *Ps. ferox* and *Ps. horrida* are expanding northward into the District.

2019 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.

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Darsie, R.F. and R.A. Ward. 2005. *Identification and Geographical Distribution of the Mosquitoes of North America, North of Mexico.* University of Florida Press, Gainesville, FL., 363 pp.

Barr, A.R. 1958. *The Mosquitoes of Minnesota (Diptera: Culicidae: Culicinae*). Univ. of Minn. Agr. Exp. Sta. Tech. Bull. 228, 154 pp.

Chapter 2 Mosquito-borne Disease

2018 Highlights

- There were no La Crosse encephalitis cases in Minnesota
- Jamestown Canyon virus caused eight illnesses in Minnesota with two in District residents
- WNV illnesses were confirmed in 63 Minnesotans, 19 occurred in District residents
- WNV detected in 132 District mosquito samples
- Collected and recycled 9,730 tires

2019 Plans

- Continue to provide surveillance and control for La Crosse encephalitis prevention
- Work with others to better understand Jamestown Canyon virus transmission
- 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

Background

District staff provide 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), Jamestown Canyon virus (JCV), and West Nile (WNV) encephalitis.

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 this 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. This 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 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.

Jamestown Canyon virus is native to North America. It is transmitted by mosquitoes and amplified by deer. Infections occasionally cause human illnesses. Documentation of JCV illness has been on the rise in Minnesota and Wisconsin. We are working to better understand the JCV cycle so that we are prepared to provide the best risk prevention service that we can.

The District uses a variety of surveillance methods to measure mosquito vector populations and to detect mosquito-borne pathogens. Results are used to direct mosquito control services and to enhance public education efforts so that the risks of contracting mosquito-borne illnesses are significantly reduced.

2018 Mosquito-borne Disease Services

Source Reduction

Water-holding containers such as tires, buckets, tarps and 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 2018, District staff recycled 9,730 tires that were collected from the field (Table 2.1). Since 1988, the District has recycled 678,790 tires. In addition, MMCD eliminated 1,993 containers and filled 478 tree holes (Table 2.1). This reduction of larval habitats occurred through inspection of public and private properties and while conducting a variety of mosquito, tick, and black fly surveillance and control activities.

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
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
2017	14,304	1,809	298	16,411
2018	9,730	1,993	478	12,201

*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 LAC encephalitis are diagnosed in children under the age of 16. In 2018, there were 78 LAC 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.

In 2018, MMCD staff collected 1,394 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. The District's adulticide treatment threshold (≥ 2 adult *Ae. triseriatus* per aspirator collection) was met in 169 aspirator samples. Adulticides were applied to wooded areas in 86 of those cases. Adult *Ae. triseriatus* were captured in 374 of 1,211 wooded areas sampled. The mean *Ae. triseriatus* capture was lower than in 2017, but similar to 2015 and 2016. (Table 2.2).

Table 2.2 *Aedes triseriatus* aspirator surveillance data, 2000 – 2018.

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
2017	1,173	361	30.8	1,334	0.98
2018	1,211	374	30.9	1,394	0.75

Aspirator sampling began during the week of May 21 and continued through the week of September 10. The first collection of *Ae. triseriatus* occurred during the week of June 4 (Figure 2.1). With the exception of the week of June 4, the rate of capture in aspirators remained near or below the long-term average for the entire season. We observed the season peak of 1.2 *Ae. triseriatus* per sample during the week of July 16.

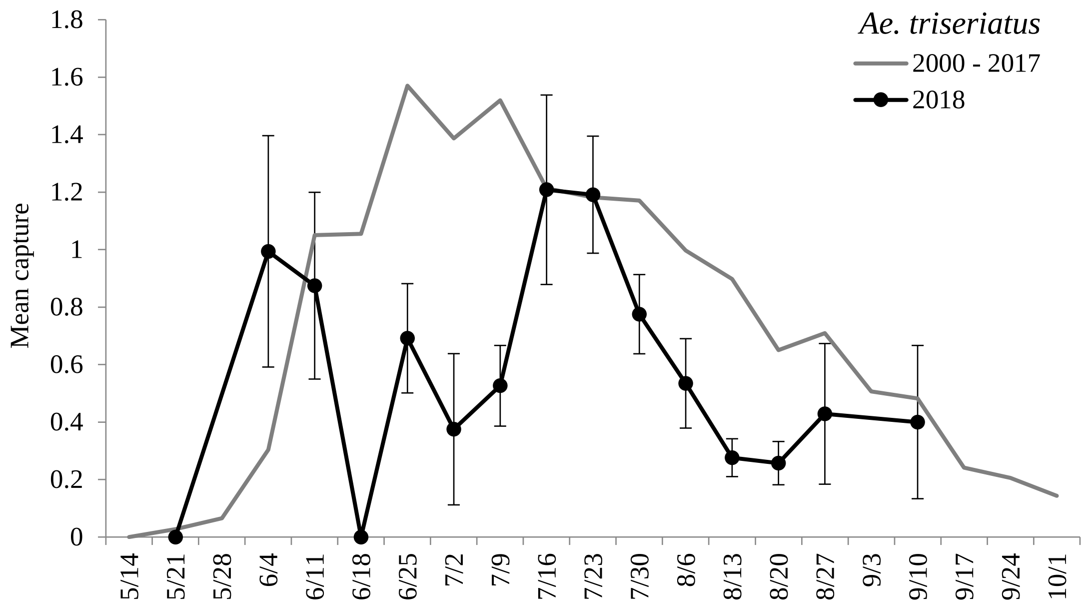

Figure 2.1 Mean number of *Ae. triseriatus* adults in 2018 aspirator samples plotted by week compared to mean captures for the corresponding weeks of 2000-2017. Dates listed are Monday of each week. There were no samples during the week of May 28 and only one during the week of June 18. Error bars equal ± 1 standard error of the mean.

La Crosse Encephalitis in Minnesota There were no LAC cases reported in Minnesota in 2018. Since 1970, the District has had an average of 2.1 LAC cases per year (range 0 – 10, median 2). Since 1990, the mean is 1.4 cases per year (range 0 – 8, median 0).

Exotic Species Each season, MMCD conducts surveillance for exotic or introduced 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 15 samples in 2018. All of the samples were collected from a tire recycling facility or adjacent properties in Scott County. Specimens were reared from seven ovitrap samples; three were collected on July 26, one each on August 8 and September 12, and two were collected on September 27. Four gravid trap samples contained *Ae. albopictus*. They were collected on July 18, August 29, September 7 and September 26. Four aspirator samples collected on July 26, August 23 and September 12 (two samples) contained *Ae. albopictus*. In 2018 we used BG Sentinel traps for the first time as a surveillance tool targeting *Ae. albopictus*. Two traps were placed near the Scott County location where the species is frequently collected and one trap was placed in an auto salvage yard in Washington County. There were no *Ae. albopictus* collected in the BG Sentinel traps.

This was the sixteenth year and seventh 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 738 samples. Most were from containers (420) and tires (128). Larvae were found in other habitats as well, including: stormwater structures/artificial ponds (110), wetlands (41), and catch basins (39).

The frequency of *Ae. japonicus* occurrence in larval samples from containers and tires has generally increased each year as they spread through the District; the species is found less commonly in tree holes (Figure 2.2). The trend in recent years may be indicative of the species becoming fully established throughout the District with weather patterns having the greatest influence on population from year to year.

Aedes japonicus adults were identified in 637 samples. They were found in 326 aspirator samples, 153 gravid trap samples, 102 CO_2 trap samples, 38 two-minute sweep samples, 13 New Jersey trap samples, and five BG Sentinel trap samples. *Aedes japonicus* were also hatched from 42 of 130 ovitrap samples collected in 2018.

In 2018, the rate of capture of *Ae. japonicus* in aspirator samples remained consistently above the average for corresponding weeks from 2011 through 2017 (Figure 2.3). While the total number of *Ae. japonicus* collected was just over half the total number of *Ae. triseriatus* in the same samples, the peak rate of capture occurred on the same week and was identical for both species at 1.2 per sample.

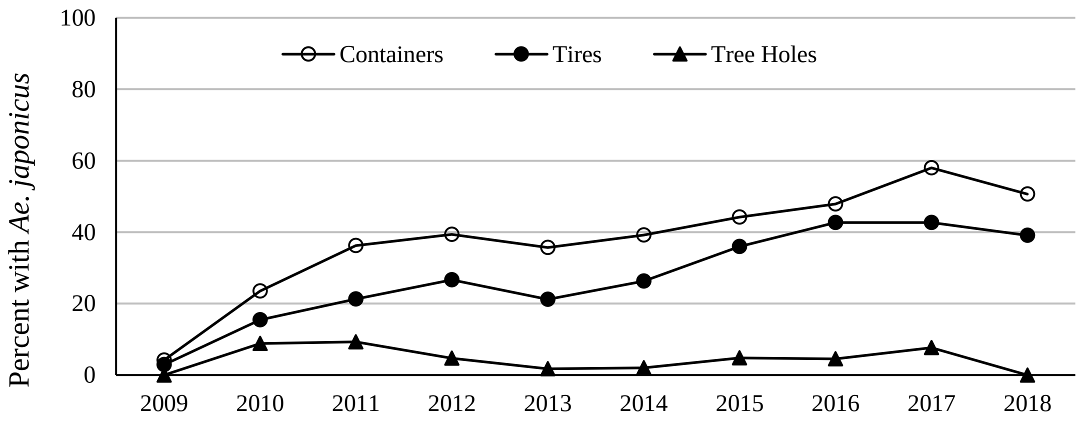

Figure 2.2 Percentage of larval samples from containers, tires and tree holes containing *Ae. japonicus* by year.

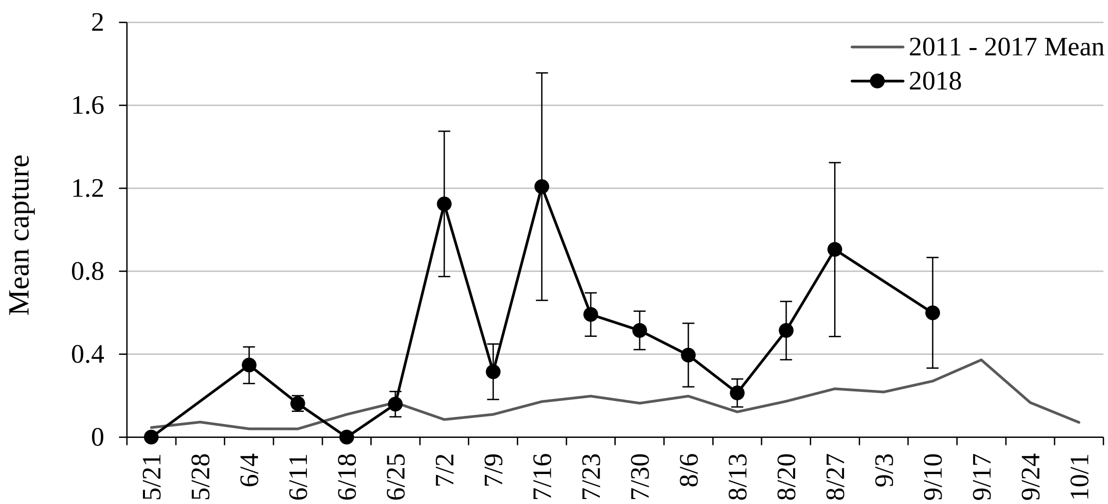

Figure 2.3 Mean number of *Ae. japonicus* adults in 2018 aspirator samples plotted by week compared to mean captures for the corresponding weeks of 2011-2017. Dates listed are Monday of each week. There were no samples during the week of May 28 and only one during the week of June 18. Error bars equal ± 1 standard error of the mean.

West Nile Virus (WNV)

West Nile virus circulates among many mosquito and bird species. It was first detected in the U.S. 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 all of the contiguous 48 states in 2018. As of this printing, the U.S. Centers for Disease Control and Prevention received reports of 2,475 West Nile illnesses from 48 states and the District of Columbia. There were 124 fatalities attributed to WNV infections. Nebraska had the greatest number of cases with 241. Nationwide screening of blood donors detected WNV in 311 individuals from 35 states.

WNV in Minnesota MDH reported 63 WNV illnesses in Minnesota residents from 30 counties. There were two WNV fatalities in Minnesota in 2018. There were also 24 presumptively viremic blood donors reported from Minnesota. Additionally, there were ten veterinary reports of WNV illness: nine in horses from eight Minnesota counties and one in an alpaca from Stearns County.

WNV in the District There were 19 WNV illnesses reported in residents of the District, nine in Hennepin County, four in Ramsey County, three in Anoka County, two in Dakota County, and one in Washington County. Since WNV arrived in Minnesota, the District has experienced an average of 10.3 WNV illnesses each year (range 0 – 25, median 8). When cases with suspected exposure locations outside of the District are excluded, the mean is 8.2 cases per year (range 0 – 18, median 6).

Surveillance for WNV One of the key influences on the WNV cycle is temperature, warmer weather is favorable for amplification of the virus. Despite a winter that seemingly extended into April of 2018, conditions were nearly ideal for WNV in May and June. Temperatures ran consistently above average from the beginning of May until the middle of July. Surveillance for the virus in mosquitoes began during the week of June 4 and continued through the week of September 24.

Several mosquito species from 44 CO_2 traps (12 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 842 mosquito pools using the RAMP® method, 132 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, 2018. MIR is calculated by dividing the number of positive pools by the number of mosquitoes tested.

Species	Number of mosquitoes	Number of pools	WNV+ pools	MIR per 1,000
Cx. pipiens	2,713	99	24	8.85
Cx. restuans	1,434	51	8	5.58
Cx. tarsalis	2,614	197	8	3.06
Cx. pipiens/Cx. restuans	8,401	328	67	7.98
Culex species	3,960	167	25	6.31
Total	19,122	842	132	6.90

The first WNV positive sample of 2018 was a pool of 43 *Culex* species collected on June 6 in Lauderdale. Eight of the season's 132 WNV positive mosquito pools were from collections of

Cx. tarsalis. One hundred twenty-four WNV positive samples were pools of *Cx. pipiens*, *Cx. restuans*, mixed pools of *Cx. pipiens* and *Cx. restuans*, or pools identified as *Culex* species.

Eighty-four of the 132 WNV positive mosquito samples were collected in Ramsey County. Sixteen of the WNV positive pools were collected in Hennepin County, 14 in Dakota County, nine in Washington County, five in Anoka County, three in Carver County and one in Scott County. Gravid traps produced 103 of the WNV positive samples while 29 were from CO_2 trap collections.

The WNV cycle received an early boost from the warm wet conditions of the first half of the 2018 season. The WNV infection rate in *Culex* species increased to 9.14/1,000 mosquitoes tested during the week of July 23 (Figure 2.4). Cooler temperatures during a three week stretch in July caused the infection rate to dip in late July and early August; however, the return of hot weather resulted in amplification of WNV to the highest level ever recorded in the District at 18.87/1000 during the week of August 27.

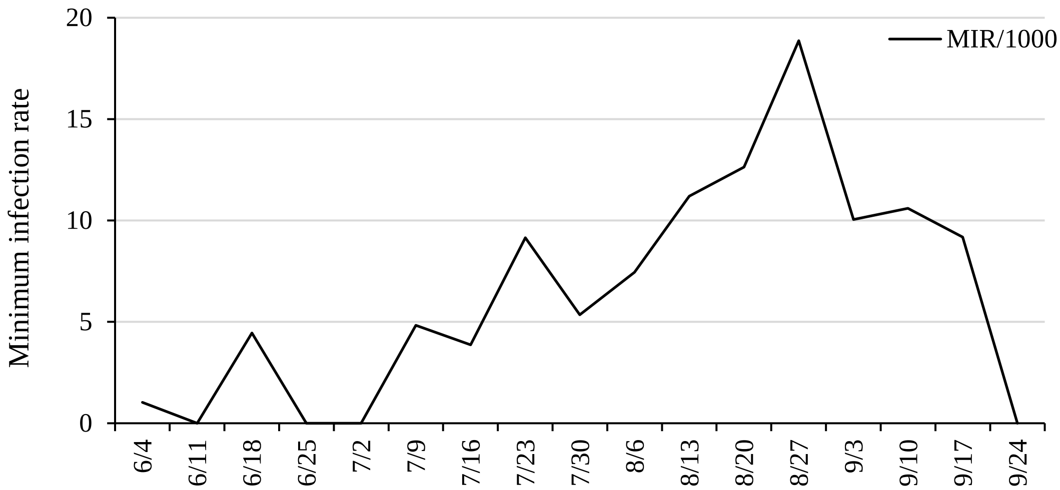

Figure 2.4 Weekly minimum WNV infection rates (MIR) per 1,000 *Culex* specimens tested in 2018. Dates listed are the Monday of each sampling week.

One bird tested for WNV by RAMP® test in 2018, the result was positive. It was an American crow collected on June 14 in Minneapolis. Bird testing was discontinued at that point, although we continued to record reports of dead birds. MMCD received 117 reports of dead birds by telephone, internet, or from employees in the field. Eight of the reports were of dead blue jays and 88 were American crows. All other reports were of non-corvids.

Adult *Culex* Surveillance

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.

Culex tarsalis is the most likely vector of WNV for human exposures in our area. Collections of *Cx. tarsalis* in CO_2 traps peaked twice, albeit at moderate levels for the District in 2018. The first occurred during the week of July 16 when the mean capture reached 6.2 per sample (Figure 2.5). The second occurred during the week of August 13 when the mean capture was 6.1 per sample. During the first population peak, most of the *Cx. tarsalis* were collected in traps south and west of the Mississippi River. The second peak was largely influenced by a high rate of capture in traps near the Minnesota River due to a mid-summer flood event caused by rainfall upstream outside of the District. As is typical, few *Cx. tarsalis* were captured by gravid trap during the entire season.

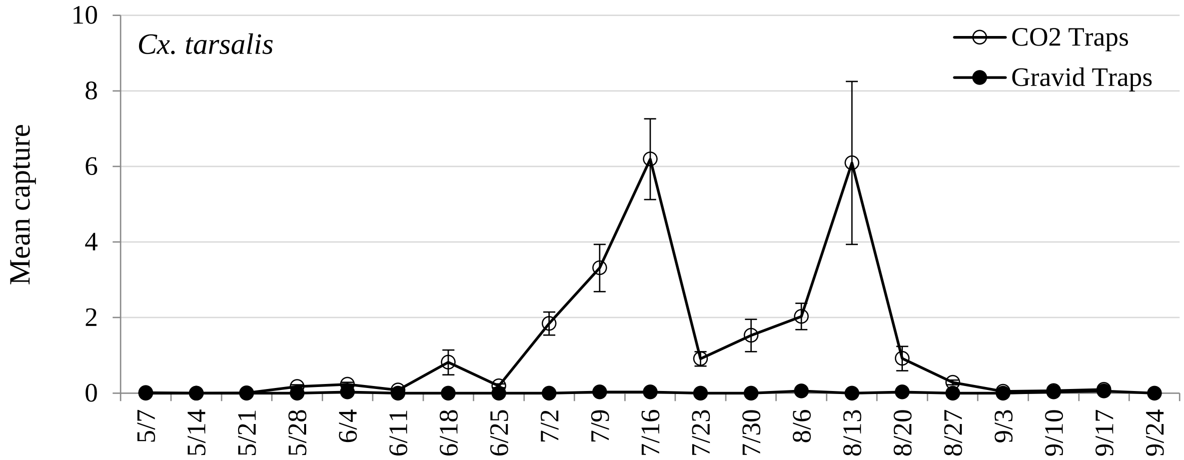

Figure 2.5 Average number of *Cx. tarsalis* in CO_2 traps and gravid traps, 2018. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

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 2018 (Figure 2.6), especially after the first week of June. The CO_2 trap captures peaked on May 28 at 4.2 per trap. Gravid trap collections of *Cx. restuans* were low for most of the season. The peak rate of capture occurred during the week of June 18 at 9.8 per trap.

Culex pipiens are important WNV vectors 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. In 2018, the rate of capture in both CO_2 traps and gravid traps increased gradually through June and both traps collected considerably more *Cx. pipiens* in the mid and late summer months (Figure 2.7). The rate of capture peaked at 14.9 per gravid trap during the week of August 13 and at 5.0 per CO_2 trap during the week of August 20.

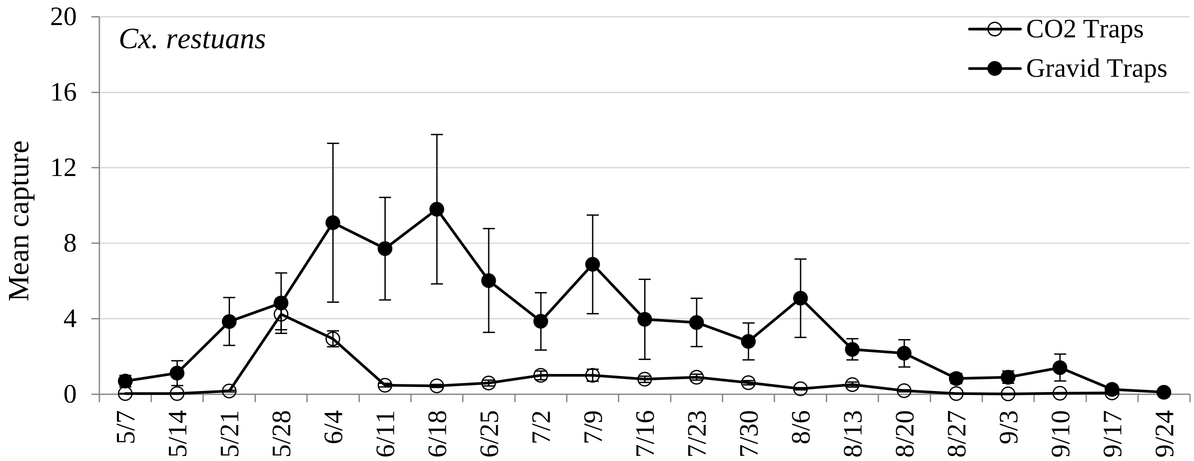

Figure 2.6 Average number of *Cx. restuans* in CO_2 traps and gravid traps, 2018. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

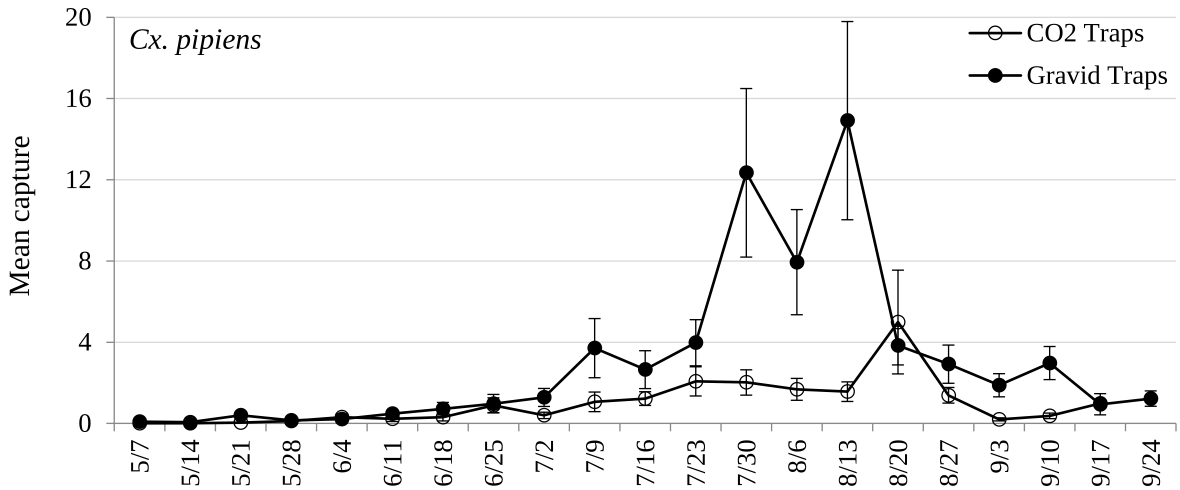

Figure 2.7 Average number of *Cx. pipiens* in CO_2 traps and gravid traps, 2018. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

When *Cx. pipiens* and *Cx. restuans* are difficult to distinguish from each other, they are grouped together and identified as *Cx. pipiens/restuans* (Figure 2.8); when only a genus level identification can be made, they are classified as *Culex* species (Figure 2.9). 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.

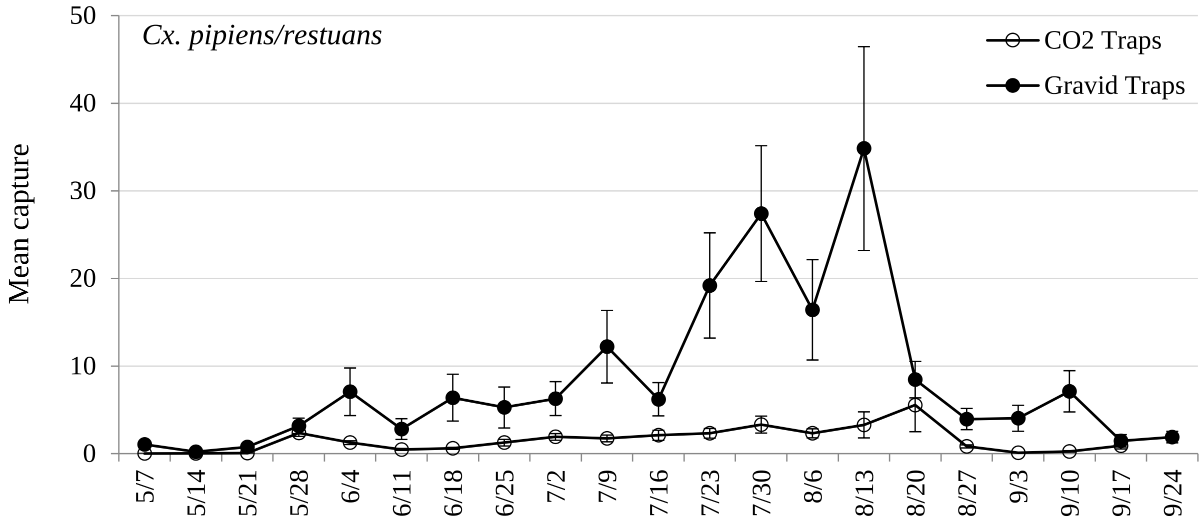

Figure 2.8 Average number of *Cx. pipiens/restuans* in CO_2 traps and gravid traps, 2018. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

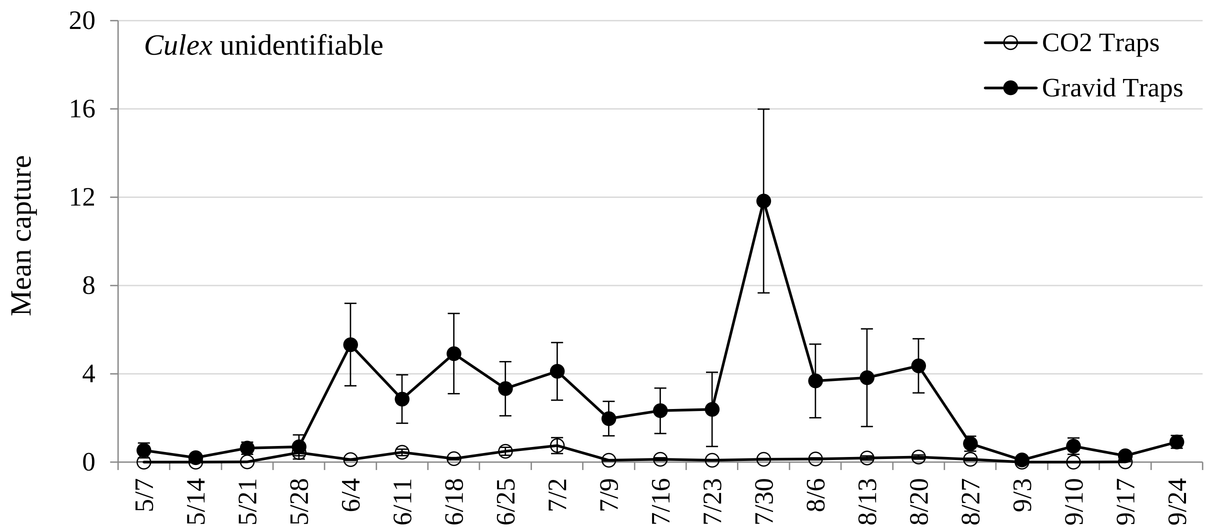

Figure 2.9 Average number of *Culex* species in CO_2 traps and gravid traps, 2018. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

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. Further-more, 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 Constructed 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, curb and gutter, swimming pools, ornamental ponds, and intermittent streams.

Inspectors collected 765 larval samples from stormwater structures and other constructed habitats. *Culex* vectors were found in 81.2 percent of the samples in 2018 (Table 2.4). *Culex pipiens* were found more frequently than in any other year dating back to 2006 from these habitat types.

Table 2.4 Frequency of *Culex* vector species in samples collected from stormwater management structures and other constructed habitats 2014 – 2018.

	Yearly percent occurrence				
Species	2014 (N=814)	2015 (N=701)	2016 (N=625)	2017 (N=627)	2018 (N=765)
Cx. pipiens	15.6	24.4	27.4	39.7	46.5
Cx. restuans	64.6	71.0	75.4	60.0	63.7
Cx. salinarius	0.6	0.4	0.0	0.5	0.0
Cx. tarsalis	5.4	2.4	3.5	3.2	1.4
Any *Culex* vector spp.	74.1	81.6	90.1	74.6	81.2

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 U.S. 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 2018, we continued the cooperative mosquito control plan for underground habitats. Eighteen 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 847 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 2018; 847 structures were treated with a total of 936 briquets.

City	Structures treated	Briquets used	City	Structures treated	Briquets used
Arden Hills	15	15	Lino Lakes	10	10
Blaine	6	21	Maplewood	225	225
Bloomington	98	115	Mendota Heights	16	16
Brooklyn Park	4	15	Minneapolis	170	170
Columbia Heights	10	14	New Brighton	5	8
Crystal	15	31	New Hope	39	52
Eden Prairie	12	20	Prior Lake	66	66
Edina	76	76	Roseville	27	29
Little Canada	3	3	Savage	50	50

Larval Surveillance in Catch Basins Catch basin larval surveillance began the week of May 21 and ended the week of September 10 (Figure 2.10). Larvae were found during 527 of 661 catch basin inspections (79.7%) in 2018.

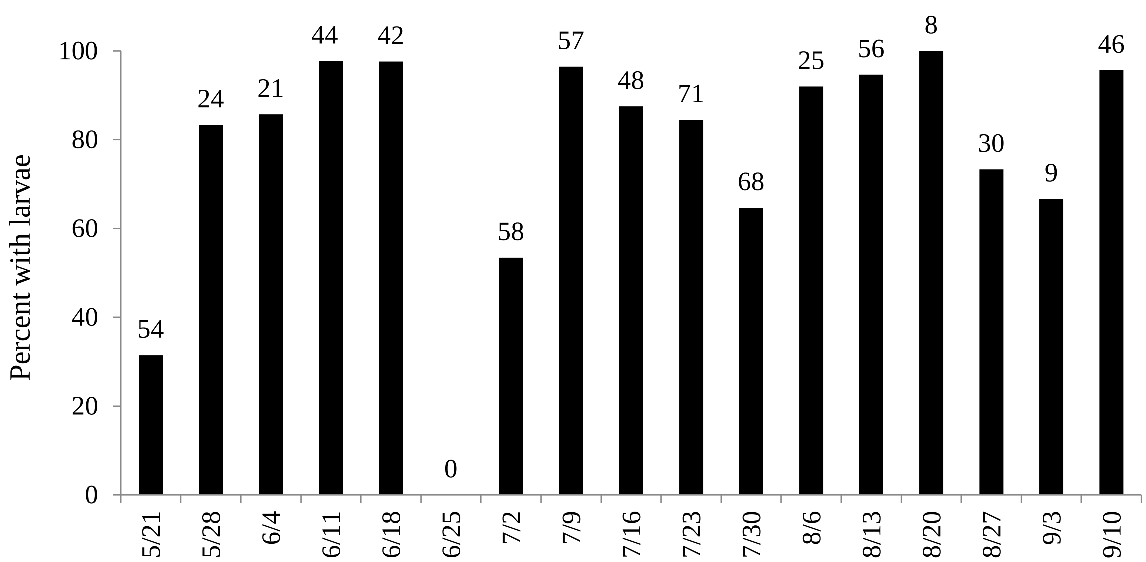

Figure 2.10 Percent of catch basins inspected with mosquitoes present in 2018. Bars are labeled with the number of inspections occurring during the week.

Mosquito larvae were identified from 526 catch basin samples. *Culex restuans* were found in 73.2% of catch basin larval samples. *Culex pipiens* were found in 66.7% of samples. At least one *Culex* vector species was found in 97.3% of samples. Both *Cx. restuans* and *Cx. pipiens* were common in catch basins throughout the season (Figure 2.11).

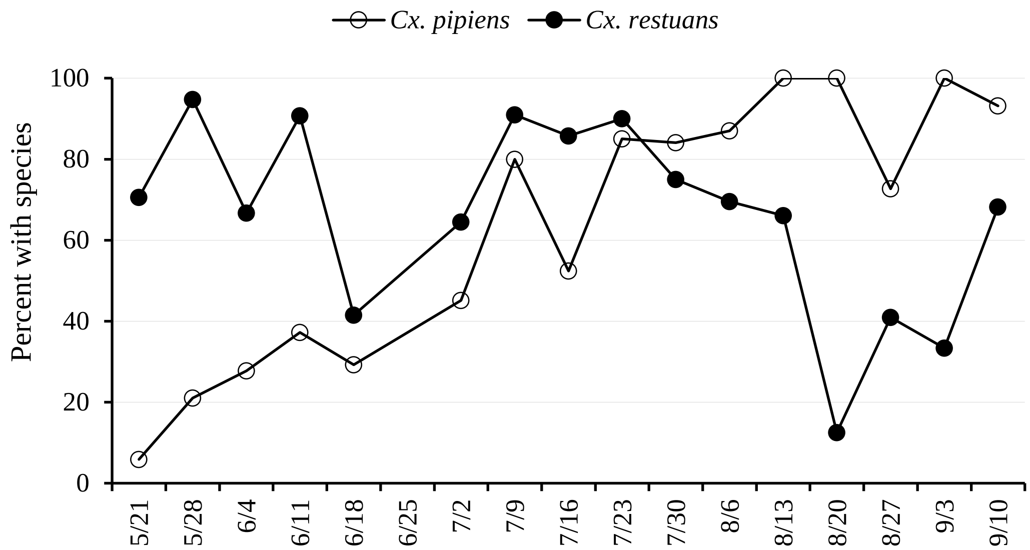

Figure 2.11 Occurrence of *Cx. pipiens* and *Cx. restuans* in catch basin larval samples by week.

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 (Mn DNR) has routinely detected antibodies to the EEE virus in wolves, moose, and elk in northern Minnesota.

In 2018, detections of the EEE virus were reported to CDC by 18 states. There were five human illnesses reported to CDC. There were non-human detections of EEE activity in 18 states primarily through veterinary reports and mosquito testing.

***Culiseta melanura* Surveillance** *Culiseta melanura*, the enzootic vectors of EEE, are relatively rare in the District and are usually 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. Larvae are most frequently found in caverns in sphagnum moss. Overwintering is in the larval stage with adults emerging in late spring. There are multiple generations per year, and progeny of the late summer cohort become 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.

The *Cs. melanura* population remained low in 2018 with a season total of only 102 adult females collected in 224 CO_2 trap placements. Fourteen pools containing 92 *Cs. melanura* were tested in the MMCD lab for EEE using the VecTOR Test Systems EEE virus antigen assay kit. All samples were negative for EEE.

District staff monitored adult *Cs. melanura* at 10 locations (Figure 1.5, p. 7) 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 feet into the tree canopy, where many bird species roost at night. The first *Cs. melanura* adults were collected in CO_2 traps on June 4 (Figure 2.12). The population remained low throughout the season with a maximum capture of 4.5 per trap on August 13.

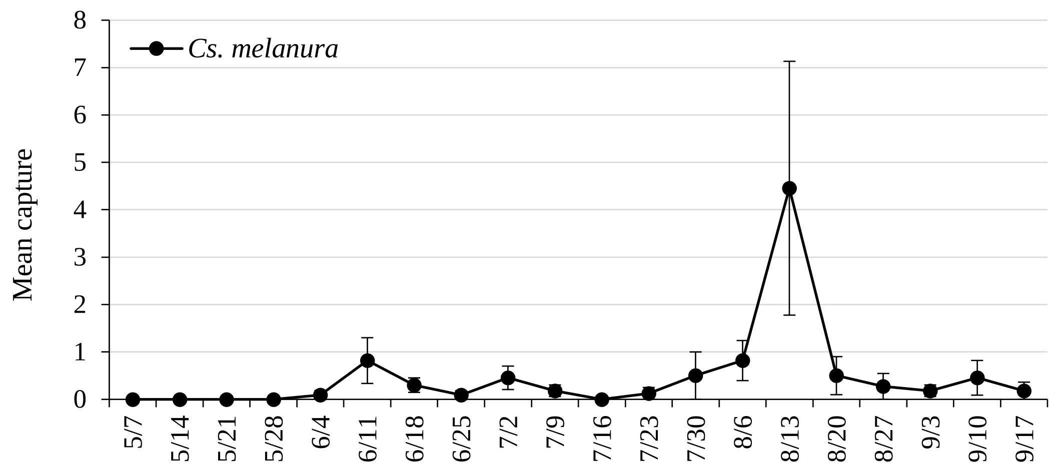

Figure 2.12 Mean number of *Cs. melanura* adults in CO_2 traps from selected sites, 2018. Dates listed are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

Staff collected 252 *Cs. melanura* in 382 aspirator samples from wooded areas near bog habitats. The first aspirator collections of *Cs. melanura* occurred during the week of June 4 (Figure 2.13). The peak rate of capture was 1.8 *Cs. melanura* per sample during the week of July 23. *Culiseta melanura* develop primarily in bog habitats in the District and they can be difficult to locate. In 2018, 10 sites were surveyed for the species. *Culiseta melanura* larvae were found in nine sites.

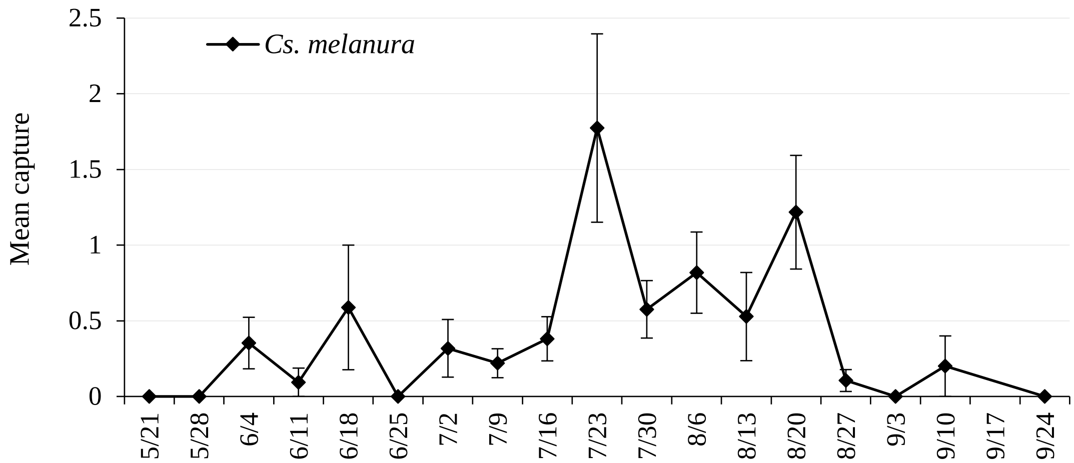

Figure 2.13 Mean number of *Cs. melanura* in 2018 aspirator samples plotted by week. Dates listed are Monday of each week. There were no samples during the week of September 17. Error bars equal ± 1 standard error of the mean.

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. There were two moderate peaks in the *Cx. tarsalis* population in 2018 (Figure 2.5).

Jamestown Canyon Virus (JCV)

Jamestown Canyon virus is native to North America and circulates among mosquitoes and deer species. The virus has been detected in many mosquito species although the role of each in transmission of JCV is not well defined. Several spring snowmelt *Aedes* species are likely responsible for maintenance of the JCV cycle and for incidental human infections. In rare cases, humans suffer moderate to severe illness in response to JCV infections.

MDH confirmed eight JCV illnesses in Minnesota in 2018. Two cases were diagnosed in residents of the District; one in a Dakota County resident and one in an Anoka County resident. Nationally, there were 34 JCV illnesses reported. Wisconsin reported 20 of the illnesses.

While dozens of North American mosquito species have returned positive results when tested for JCV, our attempts to detect the virus in mosquitoes in 2018 were focused on a few spring *Aedes* species (i.e., *Ae. canadensis, Ae. cinereus,* black-legged spring *Aedes* group, and banded-legged spring *Aedes* group). These are species that can be long-lived and therefore can take multiple blood meals. They are also species that prefer to feed on large mammals such as humans and the deer that serve as hosts for JCV. The densities of two targeted species are shown in Figure 2.14.

Very high populations have been found in northeastern Anoka and northern Washington counties.

In 2018 MMCD partnered with the Midwest Center of Excellence for Vector-borne Disease (MCEVBD) to investigate JCV transmission in the region. Collections of *Ae. canadensis*, *Ae. cinereus* and other spring *Aedes* species were pooled for JCV testing. Eighty-six pools of *Ae. canadensis*, 167 pools of *Ae. cinereus*, and 175 pools of mixed spring *Aedes* species were submitted to the MCEVBD lab at the University of Wisconsin Madison for testing. Results are pending as of this printing.

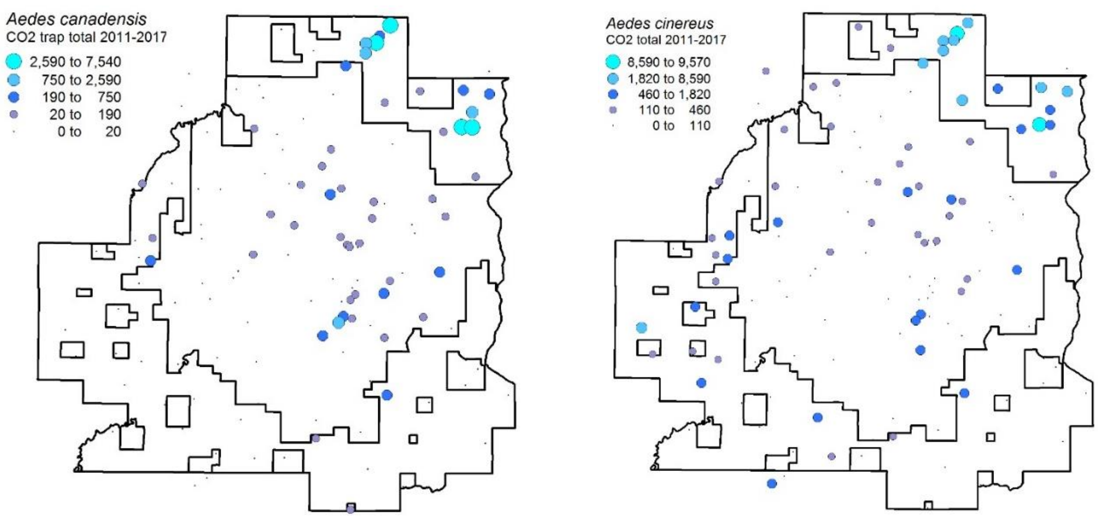

Figure 2.14 CO_2 trap collections from 2011- 2017 indicating densities of some spring *Aedes* species of concern (*Ae. canadensis, Ae. cinereus*) as possible vectors of JCV. The outer border of the map is the District border, the inner borders indicate Zone 1 and satellite communities.

2019 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 and the region.

Chapter 3 Tick-borne Disease

2018 Highlights

- 61 sites positive for *I. scapularis*
- Average *I. scapularis* per mammal was 1.50; our 2nd highest average
- *Amblyomma americanum* 1 report MMCD, 2 reports MDH from outside of the District
- 2018 tick-borne cases not available, but in 2017 Lyme cases totaled 1,408 (25.50 cases per 100,000, source MDH)
- Anaplasmosis cases in 2017 totaled 638 (11.6 cases per 100,000, source MDH)

2019 Plans

- 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, including *H. longicornis*
- Results of our collaborative study testing *I. scapularis* nymphs for tick-borne diseases is being written for publication

Background

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), the prominent vector in our area. 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.

Infected *I. scapularis* primarily transmit two important pathogens in our area. Lyme disease, a bacterial infection caused by the bacterium *Borrelia burgdorferi*, and human anaplasmosis (HA), which is caused by the bacterium *Anaplasma phagocytophilum*. Other rare pathogens transmitted by deer ticks cause human babesiosis and infection with 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. Additionally, MMCD has 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).

2018 Tick-borne Disease Services

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 have documented record-setting collection seasons on an ongoing basis. In parallel, but with a two-year lag (since 2000), the MDH has been documenting ongoing record-setting human tick-borne disease case totals. Pre-2000, the highest Lyme disease case total was 302 but since 2000 the Lyme disease 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. The all-time high HA record of 782 was set in 2011. There were 1,408 Lyme disease and 638 HA cases in 2017. Case totals from 2018 are not yet available.

Ixodes scapularis Distribution Study

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 detected *I. scapularis* with greater frequency and they appear to be prevalent now in many wooded areas south of the Mississippi River. The 2018 Lyme Tick Distribution Study report will be available on our website in June (www.mmcd.org/resources/technical-reports). Following are some preliminary 2018 highlights.

The average number of *I. scapularis* collected per mammal (1.50) in 2018 rebounded from our tabulation of 1.21 from 2017 and is our second highest tabulation to date. Our record high of 1.68 had been tabulated in 2016. However, they remain comparable to the averages we have come to expect since 2000. As shown in Table 3.1, in 14 of the last 18 years, averages have all been $\geq$ 0.81.

As has occurred in all years since 2007, except 2011, we collected at least one *I. scapularis* from all seven counties. From 2000 – 2009 our yearly positive site totals were typically in the 50s. The first time we had a site total of 70 or more was in 2010, then through 2014 our totals were either in the 50s or 70s. The first time we tabulated a site total of 80 or more was in 2015 when we had 81 positive sites, and our record high of 82 positive sites was set in 2016. We tabulated 61 positive sites in 2018. Maps are included in our yearly Lyme tick distribution study report.

Table 3.1 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, 1990-2018. 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	0.18
1991	5566	8452	6807	1094	441	73	37	0.09
1992	2544	4130	3259	703	114	34	20	0.06
1993	1543	1785	1136	221	388	21	19	0.27
1994	1672	1514	797	163	476	67	11	0.33
1995	1406	1196	650	232	258	48	8	0.22
1996	791	724	466	146	82	20	10	0.13
1997	728	693	506	66	96	22	3	0.16
1998	1246	1389	779	100	439	67	4	0.41
1999	1627	1594	820	128	570	64	12	0.39
2000	1173	2207	1030	228	688	257	4	0.81
2001	897	1957	1054	159	697	44	3	0.83
2002	1236	2185	797	280	922	177	9	0.89
2003	1226	1293	676	139	337	140	1	0.38
2004	1152	1773	653	136	901	75	8	0.85
2005	965	1974	708	120	1054	85	7	1.18
2006	1241	1353	411	140	733	58	11	0.59
2007	849	1700	807	136	566	178	13	0.88
2008	702	1005	485	61	340	112	7	0.64
2009	941	1897	916	170	747	61	3	0.86
2010	1320	1553	330	101	1009	107	6	0.85
2011	756	938	373	97	261	205	2	0.62
2012	1537	2223	547	211	1321	139	5	0.95
2013	596	370	88	42	147	92	1	0.40
2014	1396	2427	580	149	1620	74	4	1.21
2015	1195	2217	390	91	1442	291	3	1.45
2016	1374	3038	576	153	2055	252	2	1.68
2017	1079	1609	243	45	1101	204	6	1.21
2018	765	1439	219	68	1007	139	6	1.50

[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.

Tick-borne Disease Prevention Services

Identification Services and Outreach The overall scope of tick-borne disease education activities and services were maintained in 2018 including tick identifications and homeowner consultations, updating our Tick Risk Meter on our website and MMCD's Facebook page, and providing tick-borne disease information at the Minnesota State Fair and the county fairs in the metropolitan area.

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. 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.

Additional Updates – 2018

***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 U.S., but the range of *A. americanum* is known to be moving northward. *Amblyomma americanum* 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 *A. americanum* to both the MDH and MMCD (Minneapolis and Circle Pines). This trend has continued since, with *A. americanum* submitted to MMCD and/or the MDH from a variety of metro and other locations. As part of the tick submission process, each agency makes queries regarding travel history, excluding ticks that may have been picked up elsewhere. In 2017, the MMCD did not receive any reports but the MDH received one report each from Hennepin and Washington counties as well as three additional reports from outside MMCD's service boundaries. In 2018 the MDH received a report of one adult (sex unknown) and they also collected one adult female in Itasca State Park, outside MMCD's service boundaries. MMCD received one adult female *A. americanum* from Shoreview (Ramsey County). Including these 2018 submissions, between our two agencies we have totaled 27 adults and one nymph since 2009.

2019 Plans for Tick-borne Disease Services

Surveillance and Disease Prevention Services

The metro-based *I. scapularis* distribution study that began in 1990 is planned to continue unchanged. We will continue our tick-borne disease education activities and services including tick identifications and homeowner consultations, 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. 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 **and Other New or Unusual Ticks**

Lone Star Tick (*Amblyomma americanum*) MMCD and MDH continue to discuss possible strategies that would enable both agencies to detect possible establishment of the lone star tick (*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.

Longhorned Tick (*Haemaphysalis longicornus*): Possible Minnesota Introduction The longhorned tick (*H. longicornus*) was first detected in New Jersey in the fall of 2017 and is now known to have been the United States since at least 2010. It has been found mostly on the Eastern Seaboard but has also been found in Arkansas.

The longhorned tick has the potential to spread various diseases. While its principle host is cattle, it does feed on many different mammal species. In the United States, it is known to have fed on sheep, goats, horses, and cattle, and has been collected from wildlife including raccoon, opossum, and deer. It has the potential to feed on humans as well.

There appear to be two types of this tick species, and also a race that is capable of reproducing using either of the two types. The first type reproduces through mating while the other type, the type apparently introduced into the U.S., is parthenogenic, meaning a female doesn’t need to mate to produce eggs. What this means for us is that an introduction of a single female tick into an area could potentially cause the longhorned tick to become established there.

The “good news” for Minnesota is that there is some question as to temperatures and its survivability. The lowest temperatures that the known type that has been introduced into the US, the parthogenetic longhorned tick, is known to be able to withstand is 14°F. Whether it can survive in lower temperatures is unknown at this time. Also, temperatures in the range of 81°F – 86°F and higher are detrimental to egg development of the parthogenetic type of longhorned tick.

MMCD is in a good position to detect introductions of the longhorned tick. Our tick surveillance would pick up the immature stages and our staff would turn in any adult ticks to be identified. We also have had our tick identification service in place for many years and will continue to utilize Facebook to keep the public informed and to enlist their help to turn in suspected ticks.

We are partnering with other Minnesota agencies, including the MDH. All agencies will keep each other informed of any longhorned ticks found, and all ticks will be sent to Dr. Ulrike Munderloh, UM – St Paul, for confirmation of identifications.

MMCD will have a longhorned/lone star tick card ready by spring which we will use to solicit the public's assistance in finding any introductions of either species into our service area or the state of Minnesota.

Collaborative Study: Testing Nymphal Deer Ticks

In 2015, MMCD provided *I. scapularis* nymphs to PhD student Steve Bennett (University of Minnesota - St Paul campus) to be tested for exposure to several tick-borne disease agents. Nymphs from 1990 through 2014 were tested. Results are being prepared for publication.

Chapter 4 Mosquito Control

2018 Highlights

- Larvicide treatments in 2018 (189,191 acres) were slightly lower than in 2017 (195,061 acres)
- To widen control of potential Jamestown Canyon vectors, 2,786 of 20,830 acres treated to control spring *Aedes* larvae were in P2 in 2018; virtually none of 26,216 acres treated in 2017 were in P2
- 28,370 acres worth of potential larval treatments were not applied to reduce expenditures
- A cumulative total of 263,360 catch basin treatments were made in three rounds to control vectors of WNV
- Adulticide treatments in 2018 (38,479 acres) were lower than in 2017 (41,908 acres)

2019 Plans

- Apply three prehatch treatments four weeks apart (Natular® G30 early followed by MetaLarv® S-PT and Altosid® pellets)
- Continue spring *Aedes* larval surveillance in areas with high adult abundance to target potential Jamestown Canyon vectors
- Complete September VectoLex® CG treatments as part of our cattail mosquito control program
- Continue with successful expenditure reduction steps
- Work closely with MPCA to fulfill the requirements of a NPDES permit

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 target mosquito species.

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 (1-4 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 parks 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.

Three synthetic pyrethroids were used in 2018: permethrin, sumithrin and etofenprox. Sumithrin (Anvil®) and etofenprox (Zenivex®) can be used in agricultural areas. Local (barrier) treatments are applied to foliage where adult mosquitoes rest (mosquito harborage). Ultralow volume (ULV) treatments employ a fog of very small droplets that contact mosquitoes where they are active. Barrier treatments are effective for up to seven days. ULV treatments kill mosquitoes and dissipate within hours. 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 (2010-2018). Insecticide labels are located in Appendix F.

The District uses priority zones to focus service in areas where the highest numbers of citizens benefit (Figure 4.1). 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.

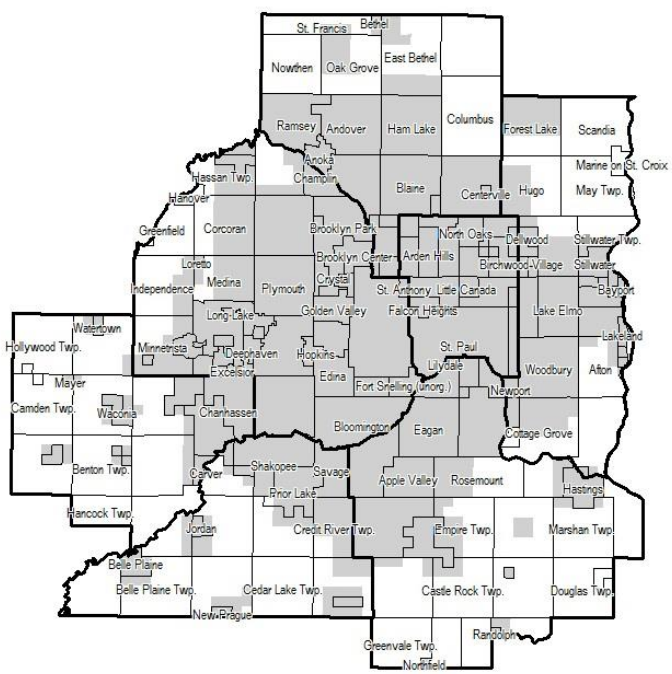

Figure 4.1 Priority zones 1 (shaded-P1) and 2 (white-P2), with District county and city/township boundaries, 2018.

2018 Mosquito Control

Larval Mosquito Control

Control Strategy Control for a season begins in the fall of the previous year, when we survey cattail sites for larvae of the cattail mosquito *Coquillettidia perturbans*. Some sites are treated with VectoLex (*Bs. sphaericus*) in the fall to eliminate larvae before they overwinter. Some sites where cattail mosquito larvae are limited to holes in cattail mats are treated with Altosid briquets (methoprene) in February when the wetlands are still frozen. Other sites with cattail mosquito larvae present are treated with controlled release methoprene products (such as Altosid pellets) by air or ground starting in late May to prevent adult emergence (usually peaking around July 4). Surveillance and control for the next season begins again in the fall (numbers reflected in 2018 control material use table).

Floodwater *Aedes* control generally uses a check-and-treat approach (i.e. check sites after rainfall event). Larval surveillance starts with the first snowmelt, and short-term control material (*Bti*) is applied where larval numbers meet a pre-determined threshold to warrant control. For treatments by ground, presence of larvae is sufficient. For treatments by air larval numbers must meet treatment thresholds, as measured by taking 10 dips with a standard 4-inch diameter dipper (Table 4.1). P1 and P2 areas can have different thresholds to help focus limited time and materials on productive sites near human population centers. Spring *Aedes*, which tend to be long-lived, aggressive biters, have a lower threshold than summer *Aedes*. However, in 2018, the spring *Aedes* threshold was raised from .5 to 1 per dip in P1 due to historically low adult numbers and the high resource use. This allowed for more resources to be available for P2 areas where numbers of adult spring *Aedes*, which are potential Jamestown Canyon virus vectors, were much higher (see Figure 2.14 in Chapter 2: Vector-borne Disease). After mid-May, when most larvae found are summer floodwater species, the summer *Aedes* threshold is used. The *Culex*4 (vector species) threshold is 2 in both priority zones. If *Aedes* and *Culex* vectors are both present in a site and neither meet their threshold, the site can be treated if the combined count meets the summer *Aedes* threshold.

Table 4.1 Larval thresholds (average number of larvae per ten dips) in priority zone by species group in 2018.

Priority zone	Spring *Aedes*	Summer *Aedes*[a]	*Culex* 4[b]
P1	1.0	2.0	2.0
P2	1.0	5.0	2.0

[a] Summer = Summer *Aedes* or *Aedes* + *Culex* 4
[b] *Culex* 4 = *Cx. restuans, Cx. pipiens, Cx. salinarius, Cx. tarsalis*

Some sites have a sufficient history of floodwater *Aedes* larvae that they are treated with controlled release materials formulated to apply before flooding ("prehatch"). This allows staff more time to check and treat other sites after a rainfall. The first prehatch treatments (Natular® G30, Altosid® pellets, MetaLarv® S-PT) were applied in mid-May with a second in mid-June and a third in mid-July.

Temporary Program Changes in Response to Budget Resource Limitations The three-year period of 2014-2016 had record high rainfall and MMCD chose to spend $5.8 million from reserves to meet the unusual service needs. Since then a combination of modest levy increases (1-3%) and spending reductions has been implemented to restore the needed reserves. More moderate weather conditions in 2017-2018 have also helped. The following are spending reduction steps started in 2017 and continued in 2018:

1. No larval treatments in P2 except for the following changes in 2018:
   - Modify summer floodwater prehatch program to shift enough control materials and personnel to treat 3,000 additional acres of cattail sites, some in P2
   - Expand larval spring *Aedes* surveillance into P2 areas with higher past adult abundance to potentially shift some spring treatments into P2 (as recommended by TAB to address JCV concerns).
2. Increase use of partial/perimeter treatment of air sites by subdividing large air sites into sections (such as perimeter/center), dipping those sections separately, and then treating only those sections that meet threshold, rather than the entire site. This strategy increases the amount of dipping required per air site, but focuses treatment on areas with the most larvae.
3. Reduce use of aerial pre-hatch treatments (30-day control) and re-allocate resources to ground pre-hatch, cattail treatments or air *Bti* treatments, aiming for a net treatment cost reduction of 22%. This requires staff to dip air sites after each rain, and thus could reduce the total number of air sites treated. Pre-hatch is less expensive only if there are three or more rain events in a 30-day period.
4. Reduce seasonal inspector hires in April by 1 per crew and add 1 in May.
5. Reduce overall labor costs by 10%.

After treating spring *Aedes* larvae with *Bti* at 8 lb/acre in May, we lowered the *Bti* rate to 5 lb/acre through the remainder of the season. No other control strategies (including adult control) were changed.

We estimate the four expenditure reduction steps involving larval control resulted in a reduction in larval treatments of 28,370 acres (Table 4.2). While significant, these temporary reductions did not represent a major larval control strategy change. As in previous years, the majority of larval control was conducted in P1. The District continued to provide some services to all citizens in the entire service area. Evaluation of the effect of these changes on adult mosquito numbers is found later in this chapter.

Table 4.2 Treatment reductions in 2018, the percent change pre-implementation of the expenditure reduction strategy in 2016, and the cost savings realized ($825,241 out of total savings of $1,155,554).

Type of treatment	Acres not treated	Percent change (from 2016 acres)	Savings
Bti treatments	7,468	-3.2	$112,398
Cattail treatments all larvicides	3,337	-8.8	$272,599
Partial/perimeter site treatments (*Bti*)	9,442	-4.0	$149,200
Pre-hatch treatment all larvicides	8,123	-21.9*	$291,044

* Percent change based on cost, not acres treated, because of shifting pre-hatch from air to ground and cattail treatments in 2018.

Spring *Aedes* Control Strategy In 2018, we expanded larval spring *Aedes* surveillance into P2 areas with higher past adult abundance to potentially shift some spring larvicide treatments into P2 to expand the area within the District that received larval control targeting suspected vectors of Jamestown Canyon virus. In 2018, we raised the P1 spring *Aedes* larval threshold from 0.5 to 1.0 larva per dip (Table 4.1) to treat sites that contained higher concentrations of larvae (in both P1 and P2). This resulted in more treatments in P2 compared to 2017, although the total acres treated for spring *Aedes* in 2018 was lower than in 2017 (Table 4.3) due to the later arrival of spring.

Table 4.3 Aerial *Bti* treatments to control spring *Aedes* in P1 and P2 in 2017 and 2018.

Habitat and material used	2017	2018
Acres treated with *Bti* P1	26,204.57	18,044.52
Acres treated with *Bti* P2	11.86	2,785.85
Total (P1 and P2)	26,216.43	20,830.37

Season Overview As described in Chapter 1, we experienced a delay to the start of the mosquito season due to unseasonably cold conditions in March and April, culminating with significant snow on April 13-14. Staff detected the first spring *Aedes* larvae on April 24, 47 days later than in 2017 (March 8). Aerial *Bti* treatments to control the spring *Aedes* brood began on May 10, seven days later than in 2017 (see Chapter 7). The mosquito species composition switched to primarily *Ae. vexans* (summer floodwater) in mid-May; the summer *Aedes* larval threshold was used after May 17. In addition to the spring *Aedes* brood, there were three large (District-wide) summer *Aedes* and nine small-medium (localized rain events) of summer *Aedes* broods – a typical season has four large broods.

Aerial prehatch treatments (Natular® G30, Altosid® pellets) to control floodwater *Aedes* were applied in early June and early July. The majority of aerial treatments to control the cattail mosquito using MetaLarv® S-PT and Altosid® pellets were applied the last ten days of May (Figure 4.2), and VectoLex® CG was applied on September 17 to control the overwintering larval population.

Overall, we applied 189,191 acres worth of larval control in 2018 which is slightly less than 2017 (Table 4.4). 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 4.4).

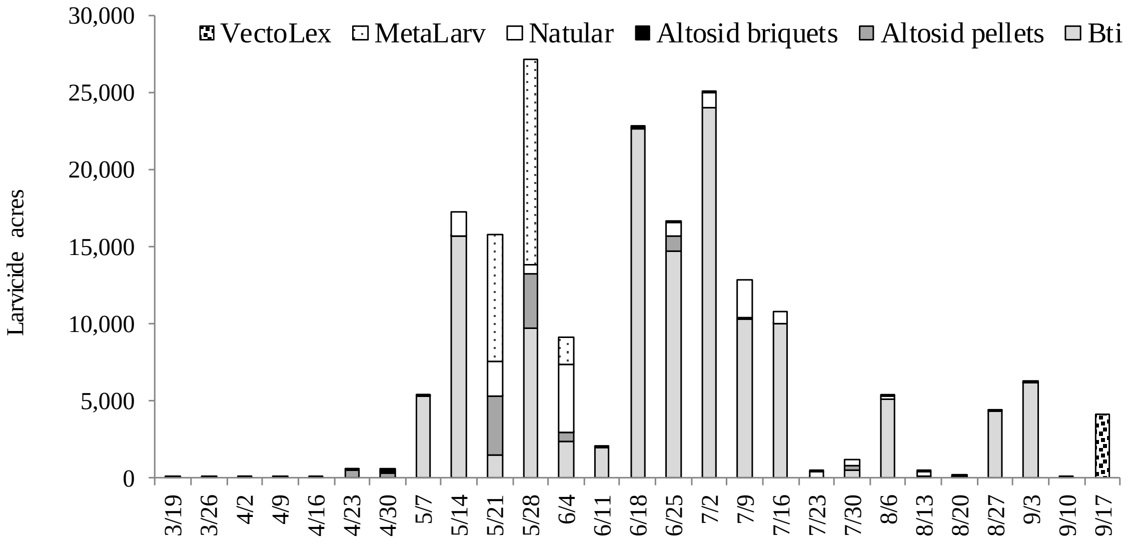

Figure 4.2 Acres treated with larvicide each week (March-September 2018). Date represents start date of week.

Table 4.4 Comparison of larval control material usage in wetlands, stormwater structures (other than catch basins) and containers, and in stormwater catch basins for 2017 and 2018 (research tests not included).

	2017		2018	
Habitat and material used	Amount used	Acres treated	Amount used	Acres treated
Wetlands and structures				
Altosid® briquets (cases)	234.19	166	236.70	167
Altosid® pellets (lb)	50,038.01	17,939	38,602.46	10,202
MetaLarv® S-PT (lb)	68,972.07	23,740	66,963.84	23,574
Natular® G30 (lb)	63,999.47	12,271	97,581.81	15,662
VectoLex® FG (lb)	71,925.00	4,773	71,834.65	4,660
VectoBac® G (lb)	888,294.62	136,173	755,355.86	134,926
Total wetland and structures		195,062		189,191
Catch basins	Amount used	CB treatments	Amount used	CB treatments
Altosid® briquets (cases)	2.02	445	2.31	509
Altosid® pellets (lb)	1,989.20	252,694	2,066.86	262,851
Total catch basin treatments		253,139		263,360

We continued to work with Minnesota Pollution Control Agency (MPCA) to make sure MMCD's larval control program satisfies the requirements of our National Pollution Discharge Elimination System (NPDES) permit, including submission of annual reports with site-specific larval surveillance and treatment records (see Chapter 7 – Supplemental Work).

Cattail Mosquito Control Reduction Evaluation In 2018, some control materials were shifted to cattail treatments to maximize treatment in P1 and restore limited treatments in P2. Cattail mosquito larvicide treatments in P2 largely were not applied in 2017 as part of a strategy to reduce expenditures. In late 2017, larval surveillance detected more sites containing cattail mosquito larvae in P1 than could be treated in spring 2018 with available resources.

Three years (2014-2016) of high precipitation flooded many acres of cattail sites. Adult mosquito surveillance documented a large increase in adult cattail mosquitoes throughout the District in 2017 (see Chapter 1 for details); abundance decreased in 2018 suggesting that dry conditions in fall 2017 and 2018 reduced water levels (and *Cq. perturbans* larval habit) in many cattail sites. Larval surveillance in late 2018 detected fewer acres of *Cq. perturbans* larval habit that require treatment in 2019 compared to 2018.

We compared adult cattail mosquito abundance in groups of CO_2 traps in P1 (cattail larvicide treatments maintained in 2016, 2017 and 2018) and P2 (limited cattail larvicide treatments completed in 2016, largely curtailed in 2017, and partially restored to 2016 levels in 2018) in Washington and Hennepin counties (Figure 4.3). Abundance in traps located in Linwood Township in Anoka County (no cattail mosquito control in 2016, 2017 and 2018) served as a reference (Figure 4.3).

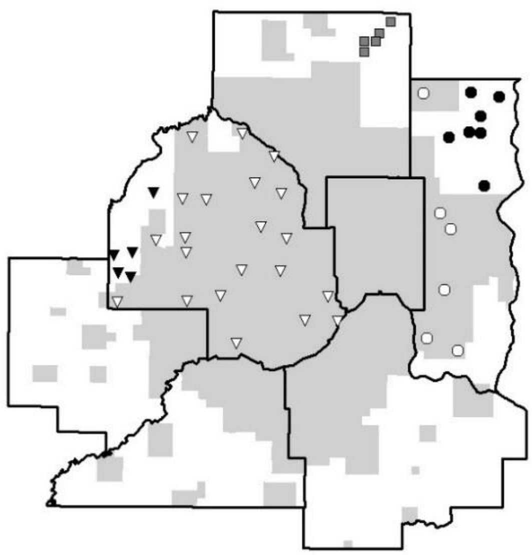

Figure 4.3 Location of CO_2 traps in Hennepin County (P1 white triangles, P2 black triangles), Washington County (P1 white circles, P2 black circles), and Anoka County (Linwood Township) (gray squares). P1 is shaded light gray.

Adult *Cq. perturbans* abundance as measured by CO_2 trap captures in 2016, 2017, and 2018 documented a large increase in 2017 throughout the District; abundance decreased in all five areas in 2018 compared to 2017 (Table 4.5). In 2016, 2017, and 2018, abundance was lower in P1 than in P2 in Hennepin and Washington counties (Table 4.5) suggesting that larval control is lowering adult *Cq. perturbans* abundance in P1.

Table 4.5 Adult *Cq. perturbans* mean abundance in Monday Night Surveillance CO_2 trap collections in 2016, 2017, and 2018 in five groups of CO_2 traps [mean (± 1 SE)]. P1 and P2 are priority treatment zones, n=number of CO_2 traps, and F, N, and L is the *Cq. perturbans* aerial larval control status*.

	Hennepin Co.		Washington Co.		Linwood Twp.
	P1	P2	P1	P2	P2
Year	(n=21)	(n=5)	(n=6)	(n=7)	(n=5)
2016	19.3 (±4.6) F	42.0 (±15.4) L	30.6 (±11.4) F	161.1 (±26.8) L	325.1 (±67.5) N
2017	57.8 (±12.7) F	158.7 (±57.1) N	123.5 (±81.9) F	424.8 (±76.7) N	750.2 (±164.1) N
2018	15.7 (±4.7) F	93.6 (±34.9) L	32.4 (±21.2) F	174.9 (±48.0) L	257.9 (±77.3) N

*Control status: F = full larval control, N = no larval control, L = limited larval control

The relative change in adult *Cq. perturbans* abundance each year was very similar in P1 and P2 of the District suggesting that environment (high precipitation in 2014, 2015 and 2016, lower precipitation in 2017 and 2018) resulted in similar relative changes of *Cq. perturbans* abundance in 2017 and 2018 throughout the observation area. The environmental impact seems to have been much stronger than potential effects of minimal larval control in P2. In 2016, 2017, and 2018, a much larger proportion of cattail mosquito breeding acreage in P1 was treated with larvicide compared to P2. When environmental conditions support high larval *Cq. perturbans* abundance, a greater proportion of breeding acreage probably will require larval control to more significantly decrease adult *Cq. perturbans* abundance.

Coquillettidia perturbans predictions for 2019 (Chapter 1: Surveillance) suggest similar abundance of this species as compared to 2018. Thus, we expect to treat fewer acres compared to 2016 which will yield additional cost savings that could be re-directed to P2 treatments or to address budget resource limitations.

Spring *Aedes* Control Strategy Evaluation The five groups of CO_2 traps used to compare *Cq. perturbans* abundance also were used to compare spring *Aedes* abundance relative to treatments in 2016, 2017 and 2018. Hennepin P1 and Washington P1 are areas where aerial *Bti* treatments targeting spring *Aedes* were completed in 2016, 2017, and 2018. Aerial *Bti* treatments were conducted in Hennepin County P2 in 2016; these treatments were not made in 2017 and limited treatments were completed in 2018. No significant aerial *Bti* treatments targeting spring *Aedes* were completed in 2016 and 2017 in Washington P2; limited treatments were completed in 2018. No significant aerial *Bti* treatments targeting spring *Aedes* were completed in 2016, 2017 and 2018 in Linwood Township.

Low and variable numbers of adult spring *Aedes* were captured by CO_2 traps which made evaluating change challenging (Table 4.6). Spring *Aedes* abundance in 2016, 2017 and 2018 in P1 (Hennepin and Washington) was essentially equal for all three years; mean abundance each year differed by less than yearly variability (1 SE) (Table 4.6). Spring *Aedes* abundance in 2016 and 2017 in Hennepin P2 was essentially equal; mean abundance each year differed by less than yearly variability (1 SE) (Table 4.6). The same was true for P2 Washington although abundance in P2 Washington appeared higher than P2 Hennepin in 2017. Abundance in P2 appeared higher in 2018 than in 2016 and 2017, especially in Washington County. Spring *Aedes* abundance in Linwood Township increased each year and was higher each year than in Hennepin and

Washington County (Table 4.6). The lack of spring *Aedes* increase in Hennepin P2 in 2017 suggests that factors other than aerial *Bti* treatments contributed to the spring *Aedes* increase observed in Washington P2 and Linwood Township.

Table 4.6 Adult spring *Aedes* mean abundance in Monday Night Surveillance CO_2 trap collections in 2016, 2017 and 2018 in five groups of CO_2 traps [mean (± 1 SE)]. P1 and P2 are priority treatment zones, n=number of CO_2 traps, and F, S, N, and L is the *spring Aedes* aerial larval control status*.

	Hennepin Co.		Washington Co.		Linwood Twp.
	P1	P2	P1	P2	P2
Year	(n=21)	(n=5)	(n=6)	(n=7)	(n=5)
2016	0.8 (±0.5) F	3.7 (±1.8) S	0.9 (±0.3) F	2.6 (±0.9) N	6.1 (±0.6) N
2017	1.0 (±0.8) F	1.5 (±0.8) N	0.4 (±0.2) F	8.5 (±5.5) N	17.6 (±4.9) N
2018	1.2 (±0.7) F	7.6 (±3.0) L	1.6 (±0.6) F	22.3 (±9.6) L	37.2 (±10.6) N

* Control status: F = full larval control, S = significant larval control, N = no larval control, L = limited larval control

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 4.7). Staff conducted a study in the early 1990s that measured peoples' 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. The sampling method used is targeted to specific mosquito species.

Table 4.7 Threshold 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. A blank cell means no threshold established for that particular species.

		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 2018, adult mosquito levels rose in late June through mid-July; at those times, counts over threshold were fairly widespread (Figure 4.4). In 2018, MMCD applied 4,227 fewer acres worth of adulticides than in 2017 (Table 4.8, Appendix E). Figure 4.3 shows weekly adulticide acres treated (line). Adulticiding steadily increased in response to widespread spring *Aedes* and *Ae. vexans* emergence in early June, and increasing numbers of *Culex* (WNV vectors) ending with the annual *Cq. perturbans* emergence continuing into the second week of July. A greater proportion of adulticide treatments later in the summer targeted vector mosquitoes. Customer calls related to mosquito annoyance peaked in June (583) and July (764) and were lower in May (357), August (96), and September (13). In 2017, annoyance calls peaked in June (1,358). Between May and September, mosquito annoyance calls were lower in 2018 (1,813) than in 2017 (2,226).

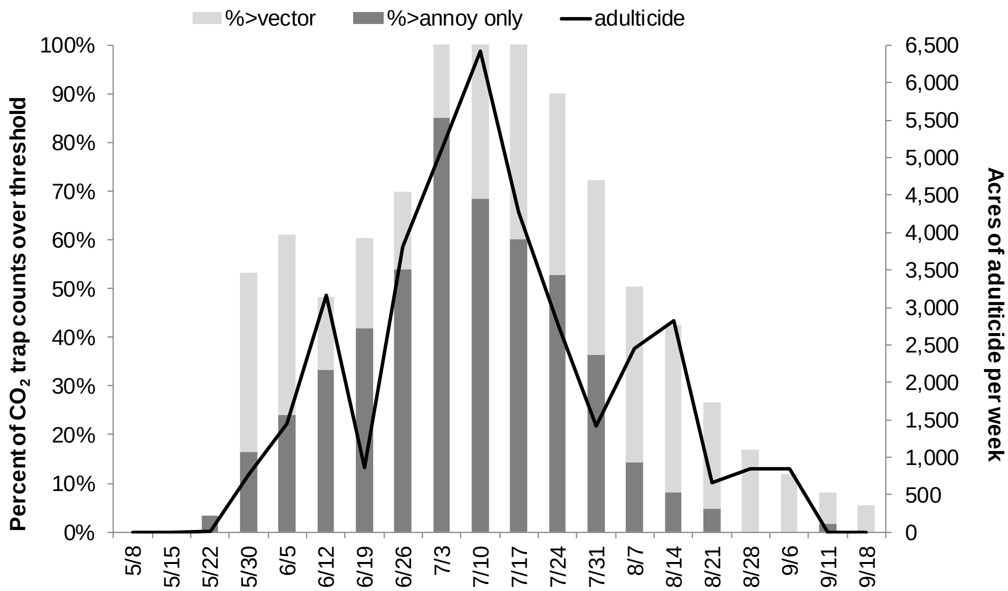

Figure 4.4 Percent of Monday CO_2 trap locations with counts over threshold compared with acres of adulticides applied in 2018 (solid line). Dark bars indicate the percentage of traps meeting annoyance mosquito thresholds and lighter bars represent the percentage of traps meeting the vector thresholds (*Culex*4, *Ae. triseriatus*, *Ae. japonicus*, *Cs. melanura*) on each sampling date. Date is day of CO_2 trap placement.

Table 4.8 Comparison of adult control material usage in 2017 and 2018.

	2017		2018	
Material	Gallons used	Acres treated	Gallons used	Acres treated
Permethrin	894.73	5,038	668.47	3,771
Resmethrin	24.29	2,090	0.00	0
Sumithrin*	299.58	11,683	191.07	7,790
Etofenprox*	205.99	23,097	295.10	26,918
Total		41,908		38,479

* Products labeled for use in agricultural areas

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.

2019 Plans for Mosquito Control Services

Integrated Mosquito Management Program

In 2019, 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 7. Our control materials budget in 2019 will remain the same as in 2018.

Larval Control

Temporary Measures to Decrease Expenditures In 2019, we plan to maintain the five expenditure reduction steps with revisions to pre-hatch and cattail treatment strategies. Because of an overall decrease of acreage meeting larval threshold for the cattail mosquito treatment observed by larval surveillance District-wide in 2018, we plan to make available more resources for prehatch floodwater mosquito control in 2019 by completing three prehatch treatments made four weeks apart (primarily Natular® G30, MetaLarv® S-PT, Altosid® pellets) using a strategy similar to that employed in 2017. These prehatch treatments should help staff reach more ground and air acres during floodwater mosquito broods, especially during periods of higher precipitation.

Floodwater Mosquitoes The primary control material will again be *Bti* corn cob granules. Larvicide needs in 2019, mainly *Bti* (VectoBac® G), Altosid® pellets, Natular® G30, and MetaLarv® S-PT, are expected to be similar to the five-year average larvicide usage (266,222 acres). In 2019 we plan to continue the spring *Aedes* larval threshold used in 2018 (1 per dip in both P1 and P2) and expand P2 treatments as resources allow to reduce potential JCV vectors in areas where human populations are present. We plan to treat spring *Aedes* sites with *Bti* at 8 lb/acre and decrease the *Bti* dosage to 5 lb/acre when we switch to the summer *Aedes* threshold. As in previous years, to minimize shortfalls, control material use may be more strictly apportioned 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 2018 (Table 4.1).

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).

Ground and aerial larvicide treatments of wetlands have been increased to control *Culex* species. 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 thereafter.

Cattail Mosquitoes In 2019, control of *Cq. perturbans* (cattail mosquitoes) will use a strategy similar to that employed in 2018. 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 Altosid pellets (4 lb/acre) and MetaLarv S-PT (3 lb/acre) aerially and by ground. Staff will complete late summer VectoLex CG applications (15 lb/acre), based upon site inspections completed between mid-August and mid-September.

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 2019 are expected to be similar to the five-year average adulticide usage (63,902 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) and Zenivex® (etofenprox) as needed to respond to elevated levels of adult mosquitoes as needed;
- to use Anvil® and Zenivex® as needed to control WNV vectors in agricultural areas because current labels now allow applications in these areas;
- to evaluate possible adulticide use in response to *Ae. japonicus* and *Cs. melanura*;
- to ensure all employees who may apply adulticides have passed applicator certification testing for both restricted and non-restricted use products.

Chapter 5 Black Fly Control

2018 Highlights

- Treated 28 small streams sites with *Bti* when the *Simulium venustum* larval population met the treatment threshold; a total of 30.6 gallons of *Bti* was used
- Made 47 *Bti* treatments on the large rivers when the larval population of the three target species met the treatment threshold; a total of 3034.2 gallons of *Bti* was used for these treatments
- Suspended larval monitoring and *Bti* treatments on the Minnesota River from mid-June through July due to flood-level flows
- Monitored adult populations using overhead net sweeps and CO_2 traps; the average black fly/overhead sweep was 0.61
- Processed non-target monitoring samples collected on the Mississippi River in 2017

2019 Plans

- Monitor larval black fly populations in small streams and large rivers and apply *Bti* when treatment thresholds are met
- Monitor adult populations by the overhead net sweep and CO_2 trap methods
- Increase larval and adult black fly surveillance near Minnehaha Creek in South Minneapolis
- Collect Mississippi River non-target monitoring samples

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 169 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 and treatment locations are shown in Figure 5.1.

2018 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.

Sampling to monitor larval populations of *S. venustum* for treatment thresholds in the MnDNR-permitted small streams was delayed from mid-April until May due to a large snowstorm. A total of 194 monitoring samples were collected using MMCD's standard sampling technique. Twenty-eight sites on 10 streams met the treatment threshold of 100 *S. venustum* per sample that was established in 1990. These sites were treated once with VectoBac® 12AS *Bti*. A total of 30.6 gallons of VectoBac was used for the treatments (Table 5.1). In comparison, the average amount of *Bti* used to treat small stream sites annually during 1996-2017 was 26.9 gallons.

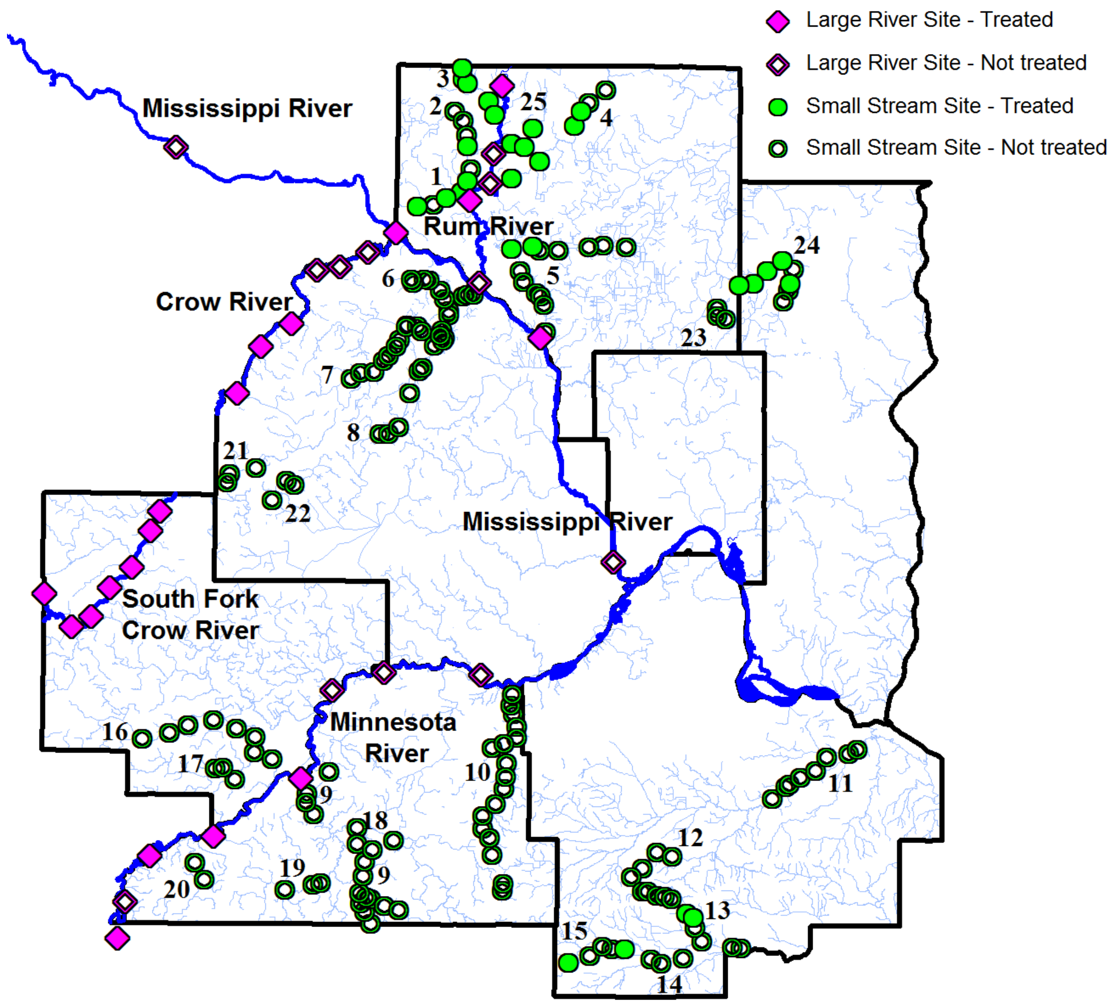

Figure 5.1 Large river and small stream black fly larval monitoring and treatment locations, 2018.

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

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 are the same treatment thresholds that have been used since 1990.

Table 5.1 Summary of *Bti* treatments for black fly control by the MMCD, 2018 vs. long-term average.

	2018			Long-term Average[1]		
Water body	# Sites treated	Total # treatments	Gal. of *Bti* used	# Sites treated	Total # treatments	Gal. of *Bti* used
Small Stream	28	28	30.6	46.6	46.6	26.9
Large River						
Mississippi	2	10	1495.0	2.1	10.9	1,158.1
Crow	3	7	150.0	2.2	5.3	94.4
South Fork Crow	7	11	69.0	5.4	12.1	106.5
Minnesota	4	7	1203.7	6.0	16.7	1,699.8
Rum	2	12	116.5	3.5	20.2	144.3
Large River Totals	18	47	3,034.2	19.2	65.2	3,203.1

[1] The Mississippi, Crow, Minnesota and Rum averages are from 1996 - 2017. The South Fork Crow is from 2005 – 2017.

A total of 339 larval monitoring samples were collected in 2018. The treatment threshold was met in 47 samples from 18 of the permitted sites; the associated sites were treated with a total of 3,034.2 gallons of VectoBac 12AS *Bti* (Table 5.1). In comparison, the average amount of *Bti* used in the large river treatments annually between 1996 and 2017 was 3,203.1 gallons with an average of 65.2 treatments. No sampling or *Bti* treatments were done on the Minnesota River from mid-June through July due to the dangerous conditions on the river from flood-level flows.

The efficacy of the VectoBac 12AS treatments is measured by determining larval mortality 250 m downstream from the *Bti* application point. In 2018, the average larval mortality of the treatments was 99% on the Minnesota River, 97% on the Rum River, 88% on the Crow River, 95% on the South Fork Crow River, and 100% on the Mississippi River.

Adult Population Sampling

Daytime Sweep Net Collections The adult black fly population was monitored at 53 standard stations (Figure 5.2) 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 AM and 10:00 AM. The average number of all species of adult black flies captured in 2018 was 0.61 (± 2.45 SD). In comparison, the average of all species captured in net sweeps from 1996 (the start of operational *Bti* treatments) to 2017 was 1.30 (± 0.82 SD) (Table 5.2). 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 SD).

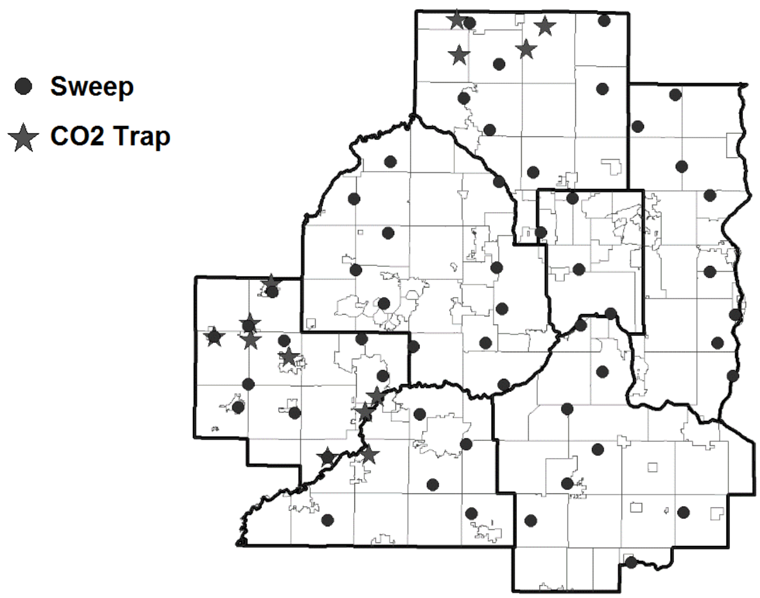

Figure 5.2 Adult black fly sweep and CO_2 trap sampling locations, 2018.

The most abundant black fly collected in the overhead net-sweep samples in 2018 was *S. meridionale*, comprising 46.8% of the total captured with an average of 0.28 (± 1.56 SD) per sample. The second most abundant black fly species captured was *S. luggeri,* comprising 41.3% of the total captured with an average of 0.25 (± 1.77 SD) per sample.

Among the seven MMCD counties, Scott County had the highest average number (1.02 ± 4.05 SD) of all black fly species captured in net sweep samples in 2018. *Simulium meridionale* was the most abundant black fly captured in Scott County with an average of 0.98 (± 4.05 SD) per sample. The most abundant *S. meridionale* larval habitat within the MMCD is located on reaches of the Minnesota River where *Bti* treatments were suspended due to the dangerous flood-level conditions from mid-June through July.

Table 5.2 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 ± SD			
		All species[5]	*Simulium luggeri*	*Simulium johannseni*	*Simulium meridionale*
No treatments	1984-1986	14.80 ± 3.04	13.11 ± 3.45	0.24 ± 0.39	1.25 ± 0.55
Experimental treatments	1987-1995	3.63 ± 2.00	3.16 ± 2.05	0.10 ± 0.12	0.29 ± 0.40
Operational treatments	1996-2017	1.30 ± 0.82	1.02 ± 0.78	0.01 ± 0.01	0.15 ± 0.12
	2018	0.61 ± 2.45	0.25 ± 1.77	0.003 ± 0.07	0.28 ± 1.56

[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 2005 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 2018 with CO_2 traps at four stations each in Scott and Anoka counties, and five stations in Carver County (Figure 5.2). The adult black fly 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 46,565 adult black flies were collected in the CO_2 traps in 2018. *Simulium meridionale* was the most abundant species, comprising 65% of the total black flies captured. Overall, 30,282 *S. meridionale* were collected in the traps, of which 22,702 were collected in the five Carver County traps. The mean number of *S. meridionale* captured in the Carver Country traps was 436.58 (± 1531.90 SD), whereas the mean number captured in the Scott County traps was 160.06 (± 364.63 SD), and 1.36 (± 4.53 SD) in the Anoka County traps (Table 5.3). The high number of *S. meridionale* captured in Scott County may have been a consequence of the suspension of *Bti* treatments during June and July.

Simulium johannseni was the second most abundant species captured in the CO_2 traps in 2018. A total of 14,793 were captured, comprising 32% of total black flies captured. The largest number of *S. johannseni* was captured in Carver County with an average of 280.79 (± 1,439.49 SD) per trap; in Scott County the average number captured was of 4.09 (± 15.70 SD). No *S. johannseni* were captured in the Anoka County traps (Table 5.3).

Simulium venustum was the third most abundant species collected in the CO_2 traps with a total of 850 captured, comprising 2% of total black flies. The largest number of *S. venustum* was captured in Anoka County with an average of 9.79 (± 39.48 SD) per trap; in Carver County the average number captured was 4.94 (± 35.50 SD), and in Scott County the average per trap was 3.87 (± 13.51 SD) (Table 5.3).

Monday Night CO_2 Trap Collections Black flies captured in District-wide weekly CO_2 trap collections were counted and identified to family level in 2018. 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 5.3. 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 early July in parts of Carver, Scott, and Dakota counties (Figure 5.3).

Table 5.3 Mean number of adult *S. venustum*, *S. johannseni*, and *S. meridionale* captured in CO_2 traps set twice weekly between May and mid-June in Anoka, Scott, and Carver counties, 2004-2018.

	S. venustum			*S. johannseni*			*S. meridionale*		
Year	Anoka	Scott	Carver	Anoka	Scott	Carver	Anoka	Scott	Carver
2004	0.89	2.25	0.25	5.11	0.17	32.93	14.09	0.65	327.29
2005	2.31	3.40	0.84	0.03	3.50	99.04	1.23	23.25	188.02
2006	22.80	3.38	1.82	0.75	38.07	98.75	0.75	10.50	107.53
2007	37.62	35.59	75.67	0.20	32.50	112.77	0.51	172.48	388.64
2008	13.84	228.93	169.63	0.13	20.18	95.63	0.68	75.03	359.02
2009	18.32	238.16	425.00	0.34	22.80	35.92	0.70	98.77	820.25
2010	21.75	44.60	77.00	0.03	6.18	219.38	0.05	256.90	271.08
2011	8.90	60.64	48.30	2.61	280.64	*4,584.72	0.93	311.55	268.28
2012	2.89	5.45	0.40	0.95	81.73	154.13	0.41	242.55	100.53
2013	14.61	3.09	1.44	1.18	4.88	14.03	0.00	111.45	322.43
2014	13.64	16.82	8.68	3.36	12.36	702.82	1.32	12.64	193.57
2015	9.83	1.14	0.43	0.37	35.17	12.43	0.17	23.31	161.30
2016	1.70	0.72	0.02	1.50	2.89	35.41	0.86	64.33	501.85
2017	7.48	2.56	1.42	6.17	6.86	71.08	1.00	38.94	298.54
2108	9.79	3.87	4.94	0.00	4.09	280.79	1.36	160.06	436.58
SD	±39.48	±13.51	±35.50	±0.00	±15.70	±1439.49	±4.53	±364.63	±1531.90
	n=4	n=4	n=5	n=4	n=4	n=5	n=4	n=4	n=5

*On May 24, 2011 over 140,000 black flies were collected in the New Germany, Carver County trap.

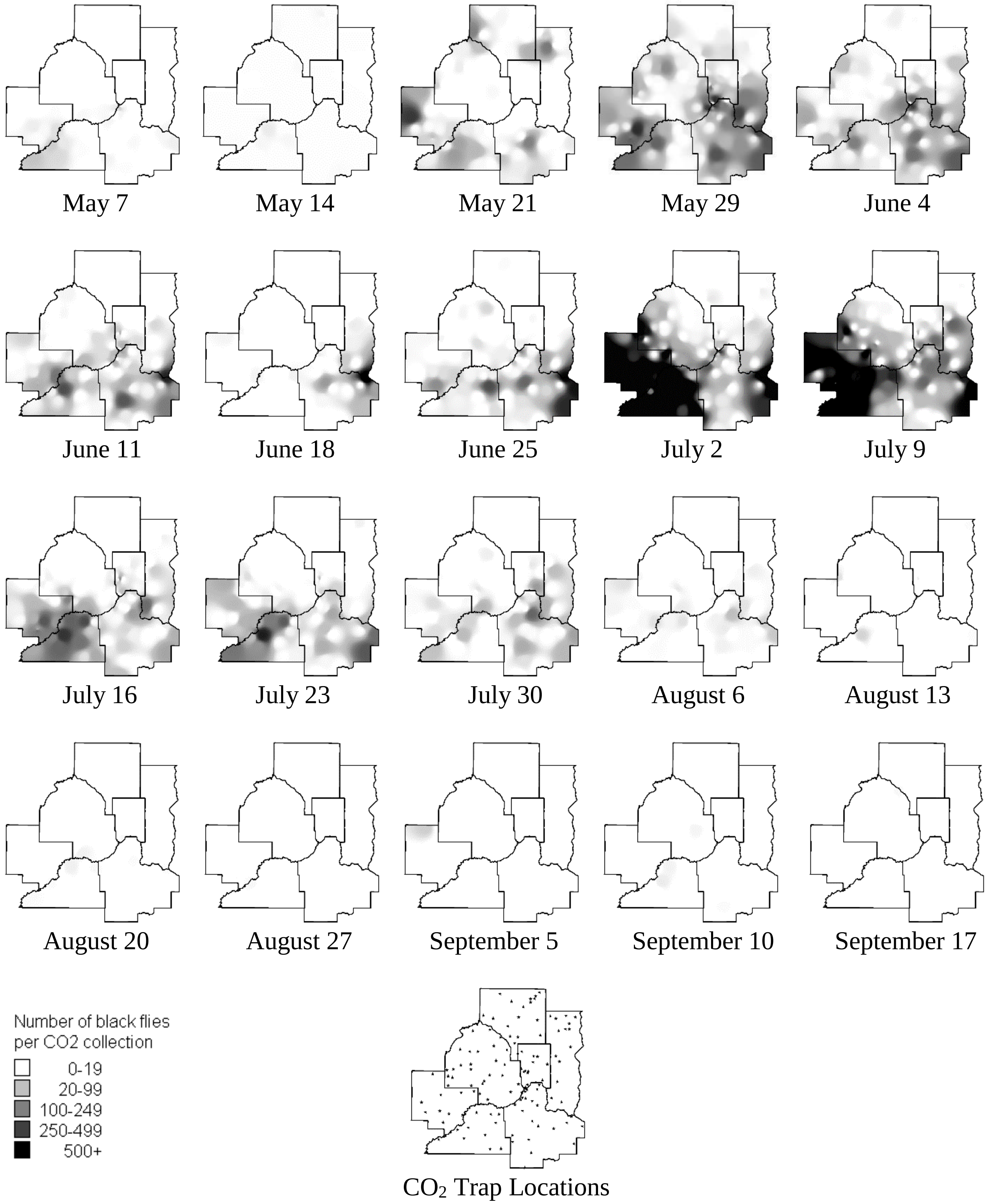

Figure 5.3 Number of black flies collected in mosquito surveillance District low (5 ft) and elevated (25 ft) CO_2 traps, 2018. The number of traps operated per night varied from 120-128. Inverse distance weighting was the algorithm used for shading of maps.

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 is a long-term assessment of the macroinvertebrate community in *Bti*-treated reaches of the Mississippi River within the MMCD. Results of the monitoring work conducted since 1995 indicate no large-scale changes have occurred in the macroinvertebrate community in the *Bti*-treated reaches of the Mississippi River. The non-target monitoring samples collected in 2017 are still being processed. A report will be submitted to the MnDNR in this coming summer.

2019 Plans – Black Fly Program

2019 will be the 35th year of black fly control in the District. The primary goal in 2019 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. Field crews will continue to use the bulk control materials containers as part of the broader sustainability efforts of the District. The 2019 black fly control permit application will be submitted to the MnDNR in February. Processing of the samples collected for the non-target invertebrate monitoring program on the Mississippi River in 2017 will be completed and a report submitted to MnDNR. Program development will continue to emphasize improvement in effectiveness, surveillance, and efficiency. Increased larval and adult monitoring will be conducted on Minnehaha Creek and nearby the neighborhoods in South Minneapolis where reports of large numbers of human-biting black flies were reported in spring of 2018. Non-target monitoring samples will be collected from the Mississippi River in 2019.

Chapter 6 Product & Equipment Tests

2018 Highlights

- Both 8- and 5-lb/acre dosages of VectoBac® G *Bti* achieved good control of *Ae. vexans* in air sites
- Natular® G (5-lb/acre) effectively controlled *Ae. vexans* in air and ground sites. We revised our efficacy evaluation procedure to dip sites at least three days after rain
- Natular® G (9-lb/acre) did not control cattail mosquitoes
- Initial tests of Sumilarv® 0.5 G did not effectively control mosquito larvae in junk yard containers

2019 Plans

- Test new formulations of methoprene against summer *Aedes*
- Evaluate efficacy of a new Natular formulation (similar to Natular® G) and a new methoprene formulation (comparable to Altosid® pellets) for possible *Cq. perturbans* control
- Explore more tests of Sumilarv® 0.5 G in containers to evaluate efficacy and potential autodissemination
- 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.

2018 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. 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 2018 were all within acceptable limits (Table 6.1). Previous year samples (2016 & 2017) were retained but not submitted due to expense of laboratory analysis.

Table 6.1 AI content of Altosid® (methoprene) briquets, pellets, and sand; MetaLarv S- PT granules (methoprene); and Natular G30 granule (spinosad), 2018.

		AI content		
Product evaluated	No. samples analyzed	Label claim	Analysis average	SE
Altosid XR-briquet	12	2.10%	2.34%	0.0157
Altosid pellets	12	4.25%	4.33%	0.0442
MetaLarv S-PT granules	12	4.25%	4.24%	0.0628
Natular G30 granules	12	2.50%	2.47%	0.0258

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 2018, 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 2018. Aerial *Bti* treatments began May 10 (seven days later than in 2017). We applied 8 lb/acre to control spring *Aedes* and switched to the 5 lb/acre rate beginning on May 31 to control *Ae. vexans*. We used the 5 lb/acre rate for the remainder of the season to conserve budgetary resources. In 2018, aerial *Bti* treatments achieved an average of 88.0% control (Table 6.2), comparable to 84.5% control in 2017, 86.0% control in 2016, 83.7% control in 2015, and 90.4% control in 2014. Effectiveness of both rates was remarkably uniform throughout the 2018 season. Percent mortality was calculated by comparing pre- and post-treatment dip counts.

Table 6.2 Efficacy of aerial VectoBac G applications (8 lb and 5 lb/acre) during different time periods of the 2018 mosquito season. (n = number of sites dipped).

Time period	Dosage rate	n	Mean mortality	±SE*
May 10 – May 26	8 lb/acre	86	91.5%	2.5%
May 31 – Sept 7	5 lb/acre	580	87.5%	1.2%
May 10 – Sept 7	All rates	666	88.0%	1.1%

*SE= standard error

Natular® G30 and *Aedes vexans* Natular G30 is used as a summer floodwater (*Ae. vexans*) prehatch. In June 2018, as part of a standard post treatment check, more larvae were found in a site previously treated with Natular G30 than we expected to find. More post treatment checks were performed. More larvae than expected were found. We increased the Natular G30 dosage for the second ground prehatch treatment in late June from 5 to 8 lb/acre.

MMCD communicated the situation to Clarke Mosquito Control (the producer of Natular G30). MMCD and Clarke worked together to determine if Natular G30 was effectively controlling *Ae. vexans* larvae. Both Clarke and MMCD responded by checking product AI levels (independent tests of samples taken from remaining Natular G30 production lots used in 2018 treatments). Clarke assayed larval mortality in the lab, including *Ae. vexans* larvae collected from sites in the District. Clarke and MMCD conducted a simple small-scale field test in August in District sites

Independent analyses of samples of Natular G30 from four production lots used by MMCD for treatments in May and early June 2018 conducted by Clarke and MMCD using the same analytical protocol indicated that spinosad levels in the Natular G30 met product specifications Table 6.3). The product quality seemed to be what it should be.

Table 6.3 Spinosad levels in samples of Natular G30 from four production lots used by MMCD for treatments in May and early June 2018 (AI specifications: 2.38 – 2.63% spinosad). SE = standard error.

	Spinosad AI level by lot number					
Analysis by:	1805250003	1709290002	1709200001	1708230001	Average	SE
Clarke	2.58	2.51	2.44	2.33	2.47	0.053
MMCD	2.54	2.39	2.47	2.41	2.45	0.034
Difference	0.04	0.12	-0.03	-0.08		

Clarke tested a sample of Natular G30 from one production lot used by MMCD with their standard pail assay used to assess the quality of product before it is approved for shipment. In this assay, pails are assembled and treated with a standard amount of Natular G30. Each week afterward a standard number of second instar mosquito larvae are added to each pail. Mortality is measured 24, 48 and 72 hours after the larvae are added to the pail. New larvae are added each week and mortality (24, 48 and 72 hours after larval introduction) is recorded to determine how many weeks the Natular G30 can control larvae after it was added when the pails are first assembled.

These lab tests demonstrated 78-100% larval mortality between 24 and 72 hours after exposure (*Ae. aegypti* [lab reared] and *Ae. vexans* [field-collected]) (Table 6.4). Natular G30 was able to control mosquito larvae including *Ae. vexans* collected in District sites and shipped to Clarke. No apparent resistance or other product problems seemed to impact product efficacy.

Table 6.4 Mortality of lab-reared and field-collected larvae exposed to Natular G30* in a standard pail assay used by Clarke for Natular G30 product quality evaluation.

Mosquito species tested	24 hr	48 hr	72 hr	Weeks after beginning of test**
Lab reared				
Ae. aegypti	78%	96%	100%	1
Ae. aegypti	100%	100%	100%	2
Ae. aegypti	100%	100%	100%	3
Ae. aegypti	100%	100%	100%	4
Ae. aegypti	84%	100%	100%	5
Field-collected				
Ae. vexans	98%	100%	100%	1
Ae. vexans	100%	100%	N/A	2

* Lot# 1805290001 used by MMCD for treatments in May and early June 2018.

** Natular G30 added at beginning of test; new batches of larvae added at one-week intervals thereafter to assess how long Natular G30 can control larvae

In August 2018, MMCD and Clarke designed a simple field test to further explore effectiveness of Natular G30 used in District treatments earlier in 2018. We chose two adjacent air sites near the P1 boundary in Hennepin County. Both sites were dipped on August 6 following significant rain on August 4. Both sites contained abundant early instar *Ae. vexans* larvae. One site was treated aerially with Natular G30 (material left over from earlier treatments) at 5 lb/acre on August 7. Both sites were dipped again on August 8, 10, and 14. Mosquito larvae only were recovered from the untreated site (Figure 6.1). Both sites were dry when they were inspected on August 22. Both sites were inspected again on August 29, four days after significant rainfall. The untreated site contained many larvae (20 per dip); very few were found in the site treated on August 7 (2 per dip) (Figure 6.1). Both sites again were inspected on September 11, six days after significant rain fall. The untreated site contained many larvae (10 per dip); very few were found in the site treated on August 7 (1 per dip) (Figure 6.1). The treated site contained higher larval dip counts than the untreated site before the August 7 treatment and much lower dip counts than the untreated site when each was inspected several times during the month following treatment. These results strongly suggest that the Natular G30 was successfully controlling *Ae. vexans* larvae.

These observations differ from post treatment dips collected in June and July in that most post treatment dips in this August test were collected four or more days after significant rain. Many post treatments dips in June and July were collected as soon as one day after rain (Figure 6.3), as is the procedure for *Bti* checkbacks. Because Natular G30 is a slow-release formulation, the aqueous spinosad concentration needs time to reach lethal levels. Larvae also need to be exposed to lethal concentrations long enough to be killed. The August air site test suggests that, in field conditions, larvae are exposed to a lethal dose of spinosad sufficient for larval control by four days after rain. Pails in lab tests did not dry down between larval additions nor did pails contain as much organic material as field sites which might account for faster larval mortality in lab tests.

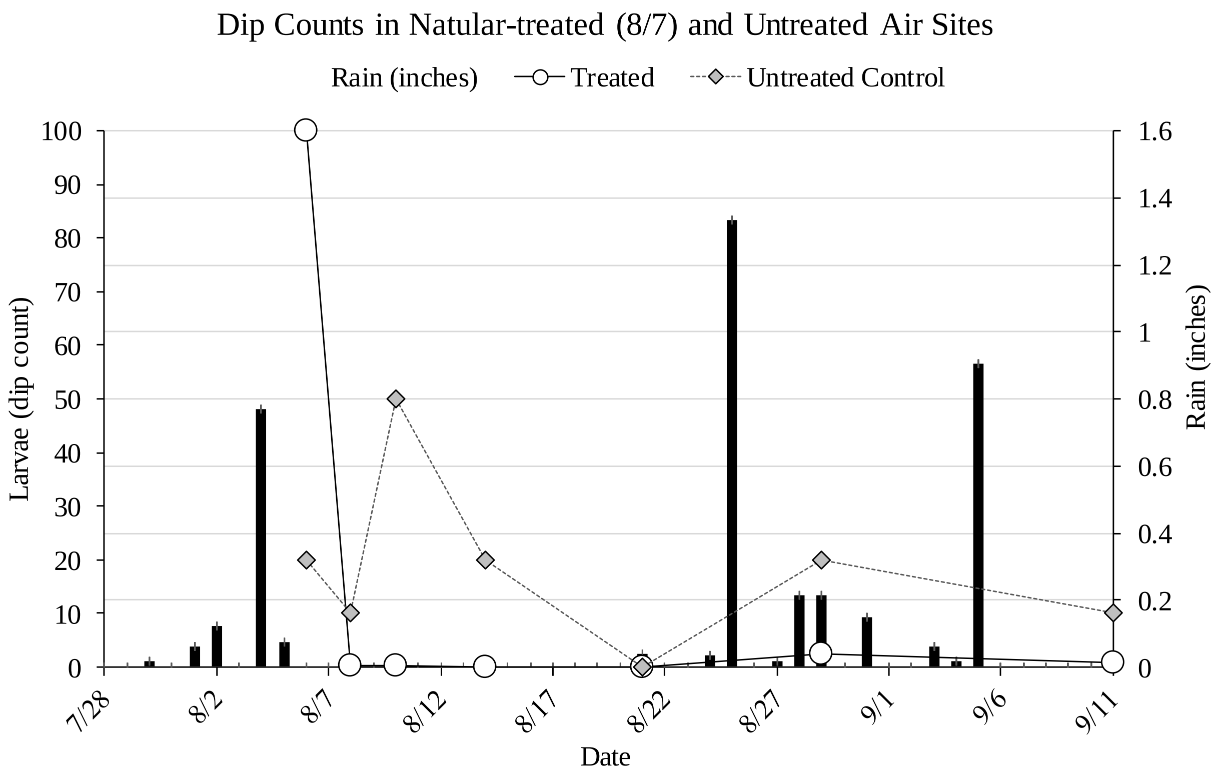

Figure 6.1 Larval dip counts in two air sites (one treated with Natular G30 on August 7) relative to rainfall.

Post treatment dip counts collected on June 21 (three days after significant rain) in ground sites treated with Natular G30 (5 lb/acre) on June 4 contained and average of 3.04 larvae per dip which is above threshold (Table 6.5, Figure 6.2). Dip counts collected from the same group of ground sites one and two days later container fewer larvae (Table 6.5, Figure 6.2). The same pattern of decreasing larval dip counts (hence abundance) in sites treated with Natular G30 is observed in sites treated on June 5 and June 28 (Table 6.5). In the future, we will need to collect post treatment dips from sites treated with Natular G30 at least three (preferably four or more) days after rain to most accurately evaluate how well Natular G30 is controlling *Ae. vexans* larvae.

Table 6.5 Larval dip counts from ground sites treated with Natular G30 on June 4, June 5 and June 28 three, four or five days after significant rain fall.

Treatment date	3 days after rain	4 days after rain	5 days after rain
6/4 (5 lb/acre)	3.04 ± 0.76 (n=159)	0.91 ± 0.23 (n=82)	0.67 ± 0.44 (n=22)
6/5 (5 lb/acre)	1.03 ± 0.46 (n=73)	0.25 ± 0.18 (n=17)	0.29 ± 0.23 (n=13)
6/28 (8 lb/acre)	1.14 ± 0.67 (n=37)	0.24 ± 0.16 (n=31)	0.65 ± 0.43 (n=13)

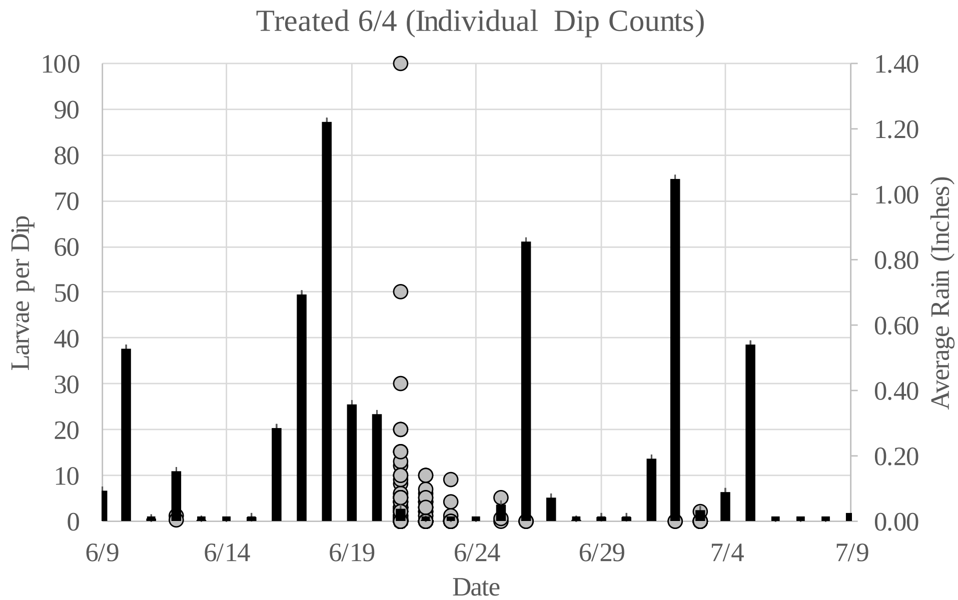

Figure 6.2 Larval dip counts from ground sites treated with Natular G30 5 lb/acre on June 4 relative to rain fall.

Another way to evaluate efficacy of Natular G30 against *Ae. vexans* larvae is to compare the post treatment dip counts from Natular G30-treated sites with post treatment dips from *Bti*-treated sites. Note that all *Bti*-treated sites also were dipped before treatment which enables calculation of a percent change (pre versus post dip) to evaluate efficacy. Post treatment dip counts from three *Bti* treatments collected one to four days after treatment did not decrease as time after treatment increased (Table 6.6) and were equal to or greater than post treatment dip counts from Natular G30-treated sites (Table 6.5) suggesting that both *Bti* and Natular G30 effectively controlled *Ae. vexans*.

Table 6.6 Post treatment larval dip counts collected one, two, three or four days after treatment with *Bti* from three significant *Ae. vexans* broods.

Treatment dates	1 day after treatment	2 days after treatment	3 days after treatment	4 days after treatment
(6/1 - 6/4)	4.89 ± 4.35 (n=23) 90.4% control	1.35 ± 0.94 (n=11) 85.4% control	2.59 ± 2.00 (n=50) 88.1% control	4.48 ± 2.52 (n=44) 85.0% control
(7/2 - 7/6)	2.68 ± 0.96 (n=43) 82.7% control	0.18 ± 0.17 (n=12) 97.1% control	1.00 ± 0.75 (n=14) 90.0% control	1.77 ± 1.32 (n=15) 83.6% control
(7/14 - 7/17)	1.12 ± 0.46 (n=41) 90.7% control	4.95 ± 1.85 (n=85) 85.5% control	3.66 ± 3.12 (n=32) 93.0% control	0.21 ± 0.13 (n=23) 98.2% control

New Control Material Evaluations

The District, as part of its Continuous Quality Improvement philosophy, strives to continually improve its control methods. Testing in 2018 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

Natular® G and *Cq.* perturbans In 2012, we completed a very small test of 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 (5 lb/acre) again in 2016 to try to determine the reasons for inconsistent results. Results again were disappointing (29% control) (see 2016 Operational Review and Plans for 2017 for details).

To compare effectiveness of a higher dosage (9 lb/acre), we treated eight cattail sites with Natular G on October 4, 2017. On June 5, 2018 we placed five emergence cages into each of the sites treated with Natular G and each of five nearby untreated sites. All adult mosquitoes in each emergence cage were collected twice each week beginning on June 8 through July 30, 2018.

Emergence of adult *Cq. perturbans* (in terms of mean adult emergence per cage) from sites treated with Natular G was slightly lower throughout the sampling period (Treated sites: 1.28 per cage, SE=0.52 than emergence from untreated sites (1.92 per cage, SE=0.74) (Figures 6.4, 6.5). This translates to 33.6% control which again is disappointing.

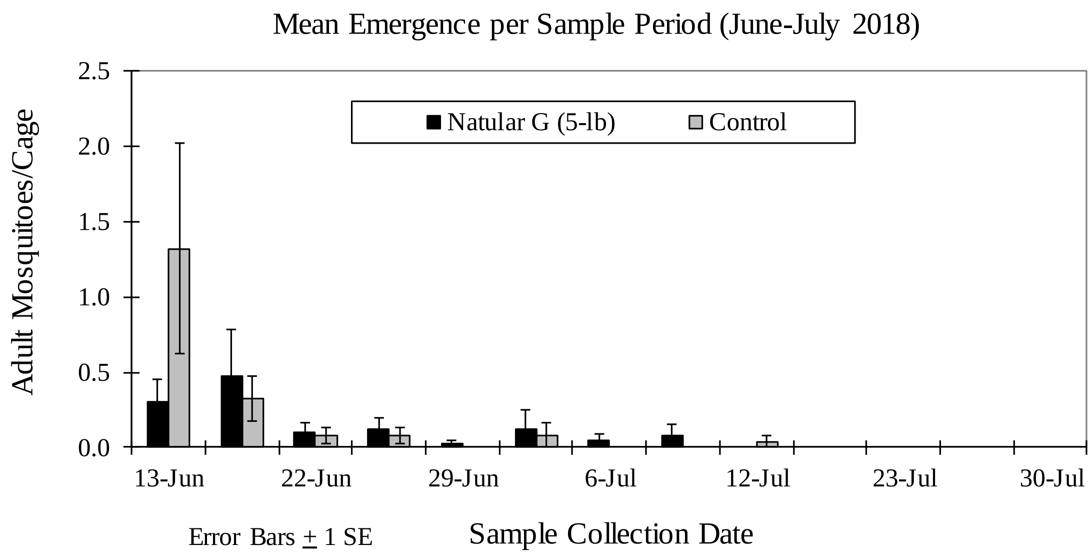

Figure 6.4 Mean emergence of *Cq. perturbans* per sample period in cages in rooted and floating sites treated with Natular G and untreated sites. Emergence cages were placed on June 5 and sampling occurred from June 13 – July 30, 2018.

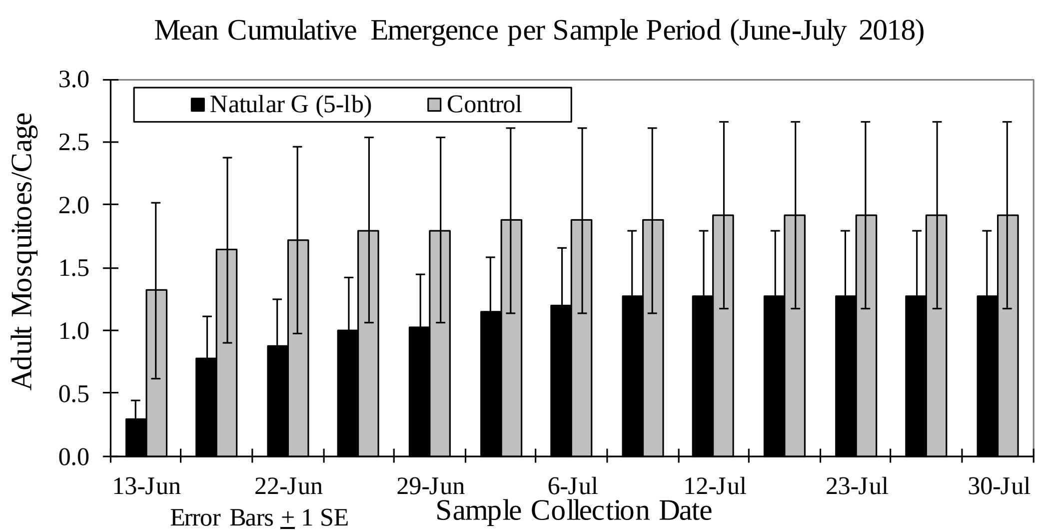

Figure 6.5 Mean cumulative emergence of *Cq. perturbans* per sample period in cages in rooted and floating sites treated with Natular G and untreated sites. Emergence cages were placed on June 5 and sampling occurred from June 13 – July 30, 2018.

Sumilarv® 0.5 G in Tires/Containers Sumilarv® 0.5 G is a granule that contains pyriproxyfen (0.5% by weight), an insect growth regulator that affects development at the fourth instar to early pupal stage, resulting in pupal mortality and prevention of adult emergence. Originally developed by Sumitomo Chemical Co. Ltd., it has been tested and used in other parts of the world since 1996 for larval mosquito control especially in containers or polluted waters (http://sumivector.com/larvicides/sumilarv). The active ingredient, pyriproxyfen, is approved by the World Health Organization (WHO) for treatment of potable water (WHO/SDE/WSH/03.04/113). Minnesota-based MGK® (McLaughlin Gormley King Company), a subsidiary of Sumitomo, is working on obtaining EPA registration for formulations designed for extended control of mosquito larvae (primarily West Nile virus vectors) in catch basins. MMCD is interested in testing different active ingredients to increase the number of tools available for mosquito control, especially formulations that might work in catch basins longer than four weeks. Initial tests of an earlier MGK formulation looked promising (MMCD 2009 Operational Review and Plans for 2010) as did tests of Sumilarv 0.5 G in catch basins in 2017 (see 2017 Operational Review and Plans for 2018 for details).

On July 9, 2018 we treated ten water-holding containers (tires or other containers) in a New Market junkyard with Sumilarv 0.5 G (1 g / 100 L, 0.1 g if 10 liters or less held by container = 50 ppb pyriproxyfen) to evaluate duration and degree of effectiveness. Effectiveness was evaluated using pupal bioassays. Larval mosquito samples were collected and identified. Adult mosquitoes that successfully emerged from pupae collected for bioassay also were identified. Pupae also were collected for bioassay from untreated containers in Lakeville and Castle Rock.

Pupal bioassays employ adult emergence inhibition (EI) that is calculated by dividing the number of pupae that did not successfully emerge (# adults minus initial number of pupae) by the initial number of pupae. EI results for bioassays from Sumilarv 0.5 G treated sites are corrected for emergence in untreated sites (background mortality) using an Abbott's formula to correct bioassay data (Abbott 1987).

Emergence Inhibition (EI) = (pupae-adults)/pupae
Corrected EI = 1 – ((1/pupae) * (adults/untreated emergence))
pupae = initial number of pupae in the bioassay sample
adults = number of adult mosquitoes that emerge successfully
untreated emergence = proportion of pupae from untreated sites from which adults emerge

Seven bioassays were collected from treated containers in New Market: three were collected less than 30 days and four were collected greater than 30 days after treatment on July 9. Six bioassays were collected from untreated containers in Lakeville and Castle Rock: five were less than 30 days and one was more than 30 days after the July 9 New Market treatment. Average mortality in bioassays from untreated containers was 16% (Table 6.9). Overall effectiveness of Sumilarv 0.5 G was very limited. No mosquitoes emerged (100% mortality) from two bioassays from treated containers collected less than 30 days after treatment (Figure 6.6). Mortality in the remaining five bioassays from treated containers was not significantly different from untreated control mortality (within the 95% confidence limit) (Figure 6.6).

Table 6.9 Bioassay results (pupal emergence inhibition=EI) of samples collected in Sumilarv 0.5 G treated (1 g / 100 L, 0.1 g if 10 liters or less held by container) and untreated (control) containers.

		EI (% mortality)				
	No. bioassays	Mean	SE	Median	Min	Max
Sumilarv	7	36.3	17.1	26.2	0.0	100.0
Control	6	16.0	4.7	14.5	0.0	32.7

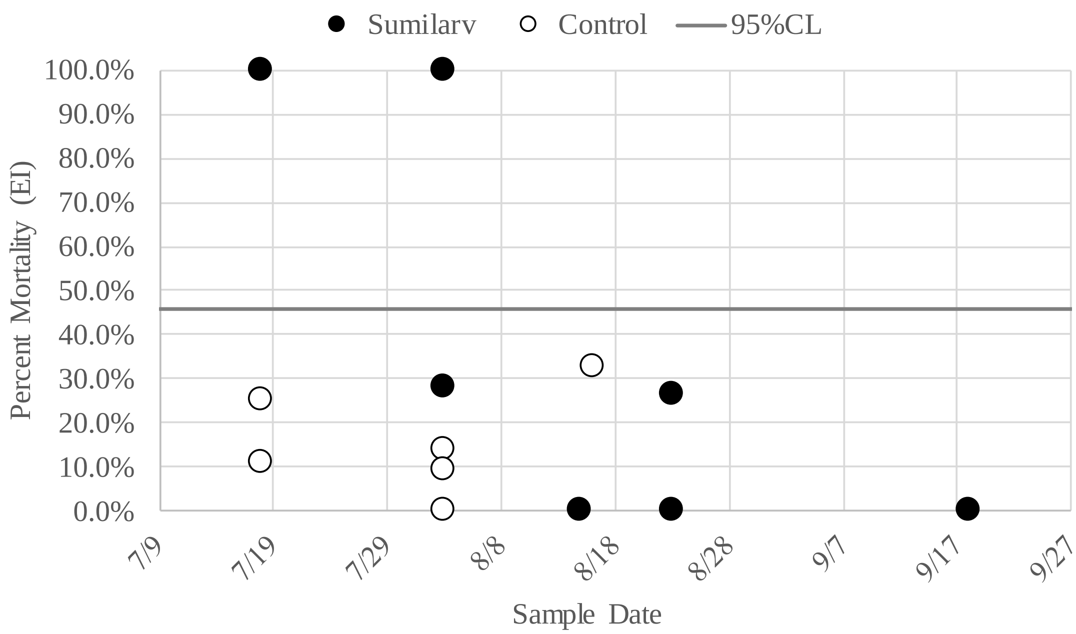

Figure 6.6 Bioassay results (emergence inhibition) of samples collected in untreated (control) and Sumilarv 0.5 G-treated containers (1 g / 100 L, 0.1 g if 10 liters or less held by container). Emergence inhibition values from Sumilarv 0.5 G treated containers were corrected for untreated control mortality. 95% confidence limits (CL) of control pupal mortality calculated using a t-distribution (df=5, t (0.05) = 2.57).

There was no evidence of different levels of effectiveness against different mosquito species. Larvae collected from treated and untreated containers included *Cx. pipiens*, *Cx. restuans*, *Ae. triseriatus*, and *Ae. japonicus* (Table 6.10). Adults of these same four species emerged from bioassays collected from both treated and untreated containers (Table 6.10). This makes sense given that pupal emergence was high in all but two bioassays.

Table 6.10 Most common mosquito species (% of samples) in larval samples collected from Sumilarv 0.5 G-treated containers and the percent of species collected as pupae that emerged as adult mosquitoes from these bioassays.

	% Samples containing larvae				% Samples containing adults			
	Cx. pipiens	*Cx. restuans*	*Ae. triseriatus*	*Ae. japonicus*	*Cx. pipiens*	*Cx. restuans*	*Ae. triseriatus*	*Ae. japonicus*
Sumilarv (N=7)	14.3	28.6	42.9	85.7	0.0	14.3	14.3	71.4
Control (N=6)	16.7	33.3	33.3	100.0	33.3	33.3	0.0	83.3

On July 9, 2018 we also treated 64 water-holding containers (tires or other containers) in a St. Paul Park junkyard with the same Sumilarv 0.5 G dosage (50 ppb). We identified an additional 32 untreated tires/containers 0.3 to 33 meters from treated tires/containers in this junkyard. Potential autodissemination was evaluated by collecting water samples from 64 treated and 32 untreated containers at the St. Paul Park junkyard at various times after treatment. Pyriproxyfen concentrations in the water samples was compared to the LD_{90} concentration (0.32 ppb) provided by Sumitomo. Water samples also were collected from treated containers at the New Market junkyard where bioassays were collected.

Between 50 and 100% of 51 water samples collected from treated containers in St. Paul Park or New Market on various dates after treatment contained detectable pyriproxyfen concentrations; pyriproxyfen concentrations in about half of these water samples were high enough to be quantified (≥0.001ppb) (Table 6.11). Only four of these 51 water samples contained pyriproxyfen levels at or exceeding the LD_{90} concentration of 0.32 ppb provided by Sumitomo suggesting that most pyriproxyfen levels were too low to cause significant larval mosquito mortality (Table 6.11). All these samples contained pyriproxyfen levels much lower than the initial amount applied (50 ppb), comparable to observations made in a similar study in northern Australia (Ritchie et. al, 2013).

Only one (1.1%) of 89 water samples collected from nearby untreated containers in St. Paul Park (a container 13 meters from the nearest pyriproxyfen-treated container sampled 71 days after treatment) contained a detectable but too-low-to-quantify (<0.001ppb) pyriproxyfen level strongly suggesting that very little autodissemination occurred during this test, certainly not enough to achieve significant mosquito control.

Table 6.11 Pyriproxyfen concentrations in water samples from Sumilarv 0.5 G treated and untreated containers in St. Paul Park and New Market. (ND = not detectable, <0.001ppb = below pyriproxyfen level that can be quantified, ≥0.001ppb = number of samples with pyriproxyfen levels high enough to be quantified, SE = standard error).

					Quantifiable (ppb)				
Days after treatment	No. of Samples	ND	<0.001ppb	≥0.001ppb	mean	SE	min	max	# > LD_{90}
Treated tires/containers									
St. Paul Park									
15	4	1	2	1	0.003	N/A*	0.003	0.003	0
28	3	1	1	1	0.015	N/A*	0.015	0.015	0
43	4	2	0	2	0.009	0.002	0.008	0.011	0
58	4	2	1	1	0.044	N/A*	0.044	0.044	0
71	29	7	11	11	0.208	0.128	0.006	1.450	1
New Market									
71	7	0	0	7	0.265	0.132	0.007	0.864	3
Untreated tires/containers									
St. Paul Park									
1	10	10	0	0	0.000	0.000	0.000	0.000	0
15	12	12	0	0	0.000	0.000	0.000	0.000	0
28	12	12	0	0	0.000	0.000	0.000	0.000	0
43	12	12	0	0	0.000	0.000	0.000	0.000	0
58	12	12	0	0	0.000	0.000	0.000	0.000	0
71	31	30	1	0	0.000	0.000	0.000	0.000	0

* SE (variance) cannot be calculated for fewer than two samples.

Adulticide Tests

In 2018 we did not complete any tests of adulticides because adult mosquito levels after mid-July (when service demands were low enough to free staff to conduct adulticide tests) were too variable to conduct high quality tests.

References

Abbott, W. S. 1987. A Method of Computing the Effectiveness of an Insecticide. Journal of the American Mosquito Control Association. 3(2): 302-303.

Ritchie,S. A., Paton, C., Buhagiar, T., Webb, G. A. and Jovic, V. 2013. Residual Treatment of *Aedes aegypti* (Diptera: Culicidae) in Containers Using Pyriproxyfen Slow-Release Granules (Sumilarv 0.5G). Journal of Medical Entomology. 50(5): 1169-1172.

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 2018 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 eight 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.

Malvern Laser: ULV Droplet Evaluations Technical Services continued the spray equipment workgroup to evaluate truck-mounted, UTV-mounted, backpack, and handheld ULV generators. Technical Services and MMCD staff use our 20 ft x 40 ft indoor spray booth to evaluate adulticide application equipment. Using the Malvern laser, staff continued to improve sampling procedures and techniques to sample the multiple types of spray equipment. MMCD evaluated the spray characteristics of all of our ULV equipment and optimized each spray system with its respective control material. All equipment was set up according to label parameters and approved for use.

Optimizing Efficiencies and Waste Reduction

Recycling Insecticide Containers MMCD continued to use the Minnesota Department of Agriculture's (MDA) insecticide container recycling program. The Ag Container Recycling Council (ACRC) program focuses on properly disposing of agricultural insecticide waste containers, thereby protecting the environment from related insecticide 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 insecticide containers in conjunction with these collections. MMCD staff collected 1,278 jugs for this recycling program. The control materials that use plastic 2.5-gallon containers are Anvil 2-2 (76 jugs), Zenivex E4 RTU (118 jugs), *Bti* liquid (621 jugs), Altosid pellets (460 jugs), and other materials (3 jugs). The purchase of a portion of the Altosid pellets and *Bti* liquid in bulk totes significantly reduced the number of jugs generated in 2018.

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 purchased mineral oil in 275-gallon bulk containers. Staff was able to reduce the overall number of 55-gallon drums purchased by 10 drums. These returnable containers do not have to be triple-rinsed and thus, reduces the District's overall generation of waste products.

Recycling Insecticide Pallets In 2018, MMCD produced over 472 empty hardwood pallets used in control material transport. Our warehouse staff worked with our vendors to 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.

We are working with Valent BioSciences to explore using the recycled materials of our empty *Bti* bags to make plastic pallets. These reusable pallets would eventually replace the need for wood pallets and be more environmentally sustainable.

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 insecticide 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 2018, 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 also sent a portion of VectoBac 12-AS liquid (1,528 gallons) in bulk totes and reduced the packaging by 634 jugs. Staff was able to spend less time dealing with waste and the District eliminated 3,564 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 2018, Valent BioSciences agreed to take back all of the waste packaging of their products. Due to the quantity (755,359 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 insecticide bags and thus, keep them out of landfills. MMCD greatly reduced their waste disposal services and estimates 7,285 lb was eliminated from our waste stream.

Hazardous Waste Collection In 2018, 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.

2019 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 2019, we plan to test new formulations of methoprene being developed by Valent BioSciences and Central Life Sciences against summer *Aedes.* These formulations are designed to be applied at lower dosages with current aerial application equipment which potentially could enable the District to support greater amounts of treatments with current budgetary resources.

We plan to place emergence cages in rooted and floating cattail sites to be treated in May 2019 with a new Natular formulation (similar to Natular G) and a new methoprene formulation (comparable to Altosid pellets) at the beginning of June 2019.

We will explore more tests of Sumilarv 0.5 G in containers. Results from both bioassays and water samples in 2018 suggest the dose used in 2018 was too low for long-term control in highly organic habitats. Tests in catch basins in 2017 using higher dosages achieved very good control suggesting that Sumilarv 0.5 G has potential to effectively control mosquitoes in containers in other situations such as junk yards.

We plan to continue tests of adulticides in different situations emphasizing control of vectors and effectiveness of barrier treatments.

Chapter 7 Supporting Work

2018 Highlights

- Added new real-time aerial treatment tracking and created display tools for phones
- Created web-based map editor for Catch Basin locations
- Explored drone use, tested application, purchased 2 drones for aerial photography, started certifying some staff as remote pilots
- Citizen call numbers were similar to previous years
- Sustainability - signed up for solar garden for electricity for most facilities
- Held two workshops involving seasonal inspectors to expand a sustainability culture

2019 Plans

- Continue exploring drone use, make drone photos available for field use, work with FAA and Mn Dept of Ag on potential for treatments
- Rewrite larval data entry to integrate more easily with web forms
- Expand efforts from initiatives to a sustainability culture

2018 Projects

Data Systems & Mapping

This year marked three major steps for MMCD's operations and data/mapping system: we added real-time tracking for helicopter treatments, started web-based editing, and explored the use of drones (unmanned aerial vehicles – UAVs).

Real-time Helicopter Tracking Real-time helicopter tracking has been a goal for years. With this year's new helicopter contract and a need to update the GPS/guidance units (Agnav), we chose to add a real-time tracking service provided by Agnav. The service shows the most recent location of each helicopter (Fig. 7.1) at 10 second intervals. This information is very useful for both field staff working with the helicopter and for front desk staff answering calls.

The basic service provided by Agnav was only available on PCs, so we worked with Houston Engineering, Inc. to tap into that service and provide an interface in MMCD's web/mobile app so that all field staff had access to this information at all times. The app worked well as long as the internet connection in the helicopter connection was working correctly. In 2019, we plan to work with the helicopter contractor to improve the connection in the helicopter. We also want to find a way to take planned treatment site boundaries, now loaded into the Agnav for the pilot, and load them into the data system as well so they can be seen with the real-time track. For calculating site treatment areas and amounts, we still use downloaded track points (collected at 0.3 sec intervals) rather than real-time points.

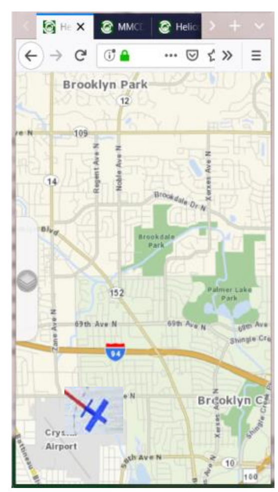

Figure 7.1 Real-time helicopter track on

Map Editing Map editing MMCD has been done using desktop GIS software for about 20 years. This gives field staff flexibility for making maps, but requires effort to pull data together from many sites and make sure it is fully standardized before using it in our web-based data system. We have been looking for ways to maintain flexible map output but standardize editing so changes are reflected throughout the system quickly, instead of as annual updates. In 2018, we developed a web-based edit interface for mapping catch basins that makes it easier to enter standard attributes, and can be used on PC or phone (Fig. 7.2). Staff are starting to use this for editing data this winter on the 288,000 catch basin locations we track. The web-based data is downloaded nightly so that staff still can make custom maps through the desktop GIS software. We plan to evaluate this and start to explore options for editing other data layers such as other water-holding structures (25,800), wetland sites (81,000), and wooded areas (28,000).

Figure 7.2 Catchbasin edit interface on web/phone

Drones Drones (unmanned aerial vehicles – UAVs) are being used increasingly by many agencies for reconnaissance and rapid capture of aerial photos. Like many ag producers, some mosquito control districts are working on ways to apply treatments by drone as well. Updates in FAA regulations have clarified requirements for general remote pilots (“Part 107”), requirements for aerial application by UAV are getting better established (“Part 137”) at the federal level, and many states are defining regulations for applicators.

After watching the industry for some time, we had an opportunity this year to work with an experienced operator on staff and test how drones might be useful for MMCD operations. In July we held an internal workshop and established a work group. Our goals for drone use are to use employee time better, improve outcomes, and better target material use to the precise habitats with larval mosquito populations. We started by testing use of drone-based images to locate and explore habitats quickly, without having to walk through risky areas such as floating mats. Eventually, we would like to test sampling and treatment options.

To date 10 MMCD staff have taken the Part 107 test and become Certified Remote Pilots. We purchased two small quadcopters [a DJI Phantom 4 V2 and DJI Mavic 2 (Fig. 7.3)] and are using them to collect updated aerial photos of wetlands that have changed since the last publicly available major photo collection, to photograph new construction sites to update our imagery, and to examine cattail mosquito habitats in greater detail. We also worked with two local companies: Sentera on near-infrared imagery (NDVI index), and PAAP Drones for a quick trial of thermal imagery

Figure 7.3 DJI Mavic

to find open water in cattail marshes. We are working on making drone-collected imagery available within our web/phone data system.

Public Web Map MMCD's public access map on www.mmcd.org continues to let people see wetland inspection and treatment activity in real time, and access history back to 2006. Data updates automatically from our internal data system developed by Houston Engineering Inc. In 2019, we hope to add more links with our data system as we update the MMCD public web site.

GIS Community MMCD staff participate in the MetroGIS collaborative, and we benefit from work by many other units of government. We use aerial photos collected by the Metropolitan Council and MnGeo, the state Geospatial Information Office, as well as those from metro-area counties as they become available. We use basemap and geocoder services from Metropolitan Council. We also share our wetland data with others through MnGeo's Geospatial Commons.

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.

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

Figure 7.4 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 1993-2018. 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 outlined box each year marks the first week with ≥ 200 DD, a number (chosen empirically from these data) approximating when spring *Aedes* larvae have sufficiently developed to warrant aerial treatment.

In 2018, the DD_{40F} total went over 200 by the end of week 19 (May 12), comparable to the latest dates in the last 20 years. Aerial treatments for spring *Aedes* (gray boxes) began that week and were completed by the end of the next week (May 19).

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

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

Week #	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	
2	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	
3	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	
4	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	
5	0	0	0	0	0	0	0	0	0	2	3	0	6	0	0	0	0	0	0	3	0	0	0	0	0	0	
6	0	0	0	0	0	0	0	0	0	2	3	0	6	0	0	0	1	0	0	3	0	0	0	0	0	0	
7	0	0	0	0	0	1	0	0	0	2	3	0	6	0	0	0	1	0	0	3	0	0	0	0	13	0	
8	0	0	0	0	0	17	0	20	0	8	3	0	6	0	0	0	1	0	0	3	0	0	0	6	41	0	
9	0	4	0	0	0	17	0	39	0	8	3	2	6	0	0	0	1	0	0	3	0	0	0	6	41	0	Last date
10	0	4	5	0	0	17	0	104	0	8	3	2	13	4	0	0	1	4	0	18	0	0	47	20	60	0	in week
11	0	9	61	12	0	17	2	104	0	8	19	3	13	4	20	2	30	49	6	135	0	3	76	104	60	0	(2018)
12	3	22	69	12	0	72	8	150	0	8	55	56	13	4	54	2	54	70	7	**306**	0	3	76	113	68	0	**Mar 24**
13	17	32	72	12	20	95	83	184	0	16	85	81	68	27	148	2	54	174	12	358	7	3	130	138	112	1	**Mar 31**
14	26	41	79	12	80	158	143	**209**	23	16	104	132	187	58	156	30	64	**236**	70	450	16	14	154	147	182	1	**Apr 7**
15	44	100	100	37	80	**234**	181	233	66	75	146	**209**	**300**	**209**	162	34	166	356	134	497	21	87	**290**	**244**	**268**	3	**Apr 14**
16	106	199	129	81	100	335	**231**	268	115	**220**	**233**	292	405	318	**281**	82	**249**	461	144	554	21	102	325	376	352	12	**Apr 21**
17	185	**245**	184	109	162	436	350	388	**213**	243	327	385	424	416	415	173	328	576	**200**	640	63	167	440	432	418	80	**Apr 28**
18	**331**	310	**273**	158	**225**	571	486	586	367	295	439	492	508	521	566	**213**	460	646	271	786	146	196	599	571	502	76	**May 5**
19	474	448	385	**220**	312	753	601	710	494	356	537	611	607	629	740	321	567	719	411	913	**267**	**302**	707	657	646	**241**	**May 12**
20	564	627	515	347	372	939	754	809	699	440	664	746	725	762	914	437	765	896	554	1112	434	378	812	790	785	400	**May 19**
21	689	796	637	492	490	1114	899	973	778	539	775	848	869	951	1075	545	923	1146	692	1280	570	527	979	1002	914	585	**May 26**
22	791	977	810	627	616	1210	1069	1111	910	755	939	1005	1059	1205	1274	690	1071	1341	905	1442	733	748	1148	1093	1095	808	**Jun 2**
23	993	1152	970	753	811	1345	1290	1305	1060	913	1093	1204	1292	1417	1457	873	1202	1512	1121	1681	868	944	1356	1408	1345	1057	**Jun 9**
24	1153	1392	1192	967	1017	1558	1424	1462	1276	1117	1273	1388	1500	1633	1732	1059	1432	1721	1316	1881	1067	1111	1565	1635	1591	1260	**Jun 16**

Figure 7.4 Cumulative Degree Days (base 40 °F, 4.4 °C) from January 1, MSP Airport.

Evaluating Nontarget Risks

Previous Nontarget Work At the direction of the TAB, MMCD has done studies over the years on possible nontarget effects of the control materials we use. Studies on Natular (spinosad) done in 2014-2015 have been discussed in previous Annual Reports. 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 minimize negative effects on pollinators, including the rusty patched bumble bee (*Bombus affinis*) which was listed by the U.S. Fish and Wildlife Service as an endangered species under the Endangered Species Act effective March 21, 2017. 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.

In 2018, MMCD consulted with the U.S. Fish and Wildlife Service about the degree of risk of MMCD's mosquito control operations to the rusty patched bumble bee. We reviewed the annual biology of the rusty patched bumblebee with when and where mosquito control operations occur during the season and were able to conclude that the overall risk of MMCD's mosquito control operations to the rusty patched bumblebee is very low.

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.

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 insecticides to water, and Minnesota Pollution Control Agency (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

MMCD's Pesticide Discharge Management Plan (PDMP) describes contact people, target pests and data sources, thresholds and management, and steps to be taken to respond to various types of incidents. This plan has been renewed annually since 2012, along with submitting our Notice of Intent and fees every 5 years (most recently in 2016).

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.

U.S. Fish & Wildlife Service – Mosquitoes and Refuges MMCD works with the U.S. 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 July 19, 2018 MMCD requested permission to survey wetlands within the Minnesota Valley National Wildlife Refuge during the following week. That request was approved on July 20. From July 25 through July 27, MMCD staff surveyed 57 wetlands within the refuge. Mosquito larvae were found in 19 of the sites. *Culex tarsalis*, the primary target of the surveillance effort, was collected from three sites. Other species found included *Anopheles quadrimaculatus*, *An. punctipennis*, *An. walkeri*, *Uranotaenia sapphirina*, and *Cx. territans*.

Adult mosquito surveillance using CO_2 traps (Chapter 1) was evaluated using eight traps near MVNWR. *Aedes vexans* was collected starting May 22, with highest populations from late June through late July, and collections were greatest in the five traps within one mile of the refuge, vs. the three traps over two miles away. Collections of *Cx. pipiens* and/or *Cx. restuans* were relatively low at locations near MVNWR in 2018. *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* collections increased following the July flooding of MVNWR, peaked on July 17, and then peaked again on August 14. For the eight traps evaluated, most of the high counts of *Cx. tarsalis* were in traps less than a mile from the refuge, but numbers were variable.

Mosquitoes collected from traps near MVNWR were tested for WNV from the beginning of June through the end of September. There were nine WNV positive samples from the area in 2018. Seven were from trap location DSR7 in Eagan (0.8 mi from the refuge) from June 19 to September 6 (2 *Cx. tarsalis*, 1 *Cx. pipiens*, 4 *Cx. pipiens/restuans*). Also positive for WNV were a pool of *Cx. pipiens/restuans* from location S015 (2.7 mi away) on July 17 and a pool of *Cx. pipiens* from location FS1 (0.6 mi away) on August 21.

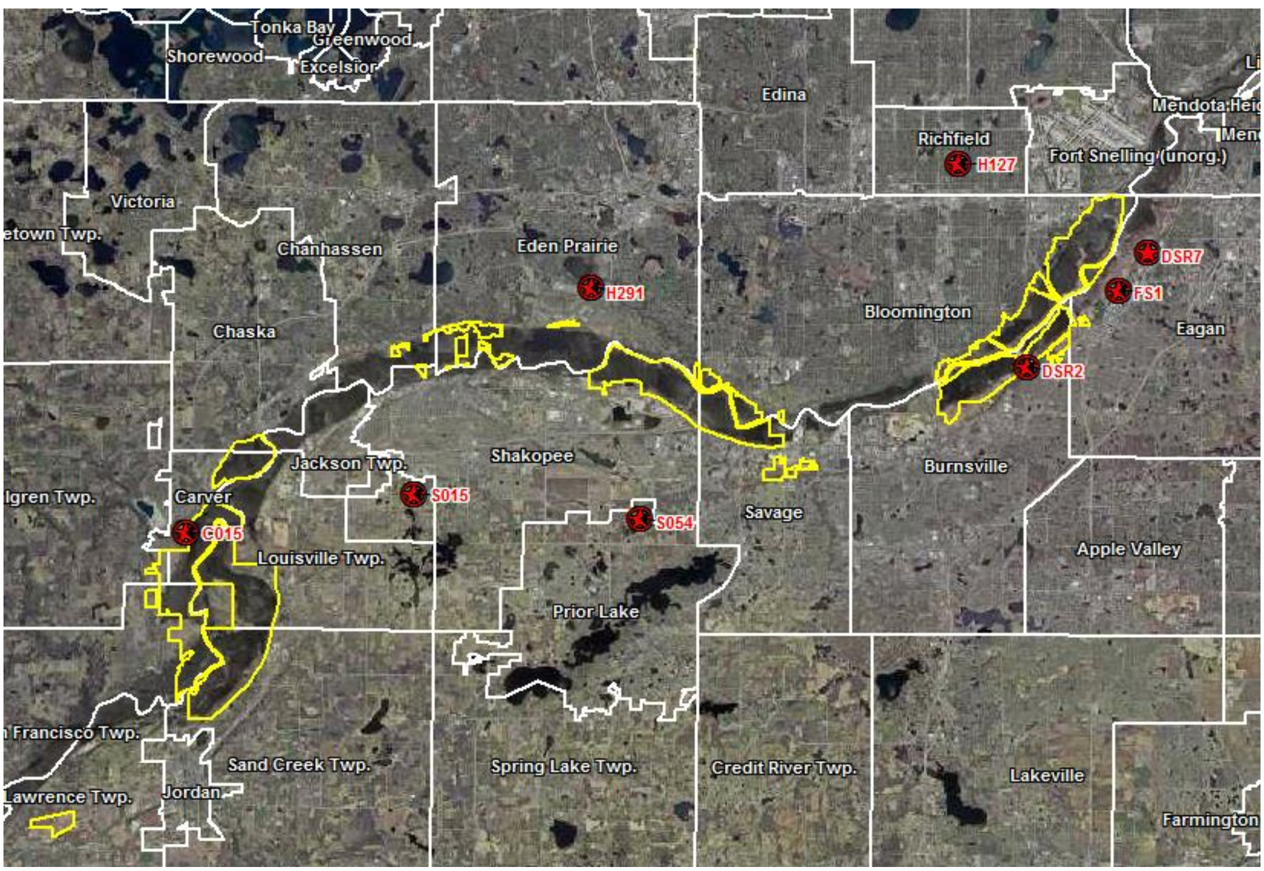

Figure 7.5 CO_2 trap locations (circles with red stars) near the MN Valley National Wildlife Refuge.

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. Notice is also available through GovDocs (Granicus).

Calls Requesting Service The most frequent type of call from the public continues to be requests for larval or adult mosquito treatment. In 2018, the number of these calls peaked the week of July 2, concurrent with a surge in mosquito abundance. Calls and mosquito abundance both dropped off after that and continued to decline through Labor Day weekend (Figure 7.5).

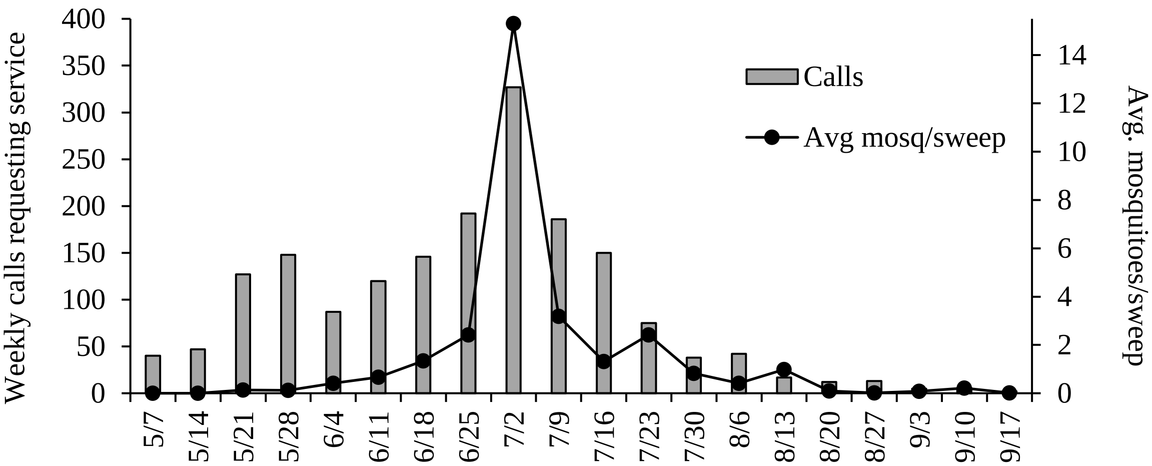

Figure 7.5 Calls requesting service, and sweep net counts, by week, 2018.

Requests specifically asking for adult mosquito treatment remained high in 2018. (Table 7.1). Calls requesting site checks for larval mosquitoes decreased in 2018 to more typical levels. The total calls for request or confirmation of limited or no treatment appears higher than in earlier years because since 2014, we have used this part of our Call System to record all bee hive locations we become aware of through Driftwatch or independent reports.

Table 7.1 Yearly citizen call totals (including e-mails) by service request type, 2008-2018.

	Number of calls by year										
Service request	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Check a larval site	220	197	164	626	539	609	1,068	447	886	1,158	601
Request adult treatment	1,375	594	1,384	1,291	1,413	1,825	2,454	1,633	2,499	1,169	1,215
Public event, request treatment	108	71	78	67	61	70	93	91	105	101	91
Request tire removal	254	305	332	315	417	351	429	366	377	363	325
Request or confirm limited or no treatment	66	58	53	56	54	[a]136	[b]146	139	158	126	76

[a] Historic restriction "calls" moved into new system
[b] Bee hive locations added into call system to track restrictions

Curriculum in Schools Main Office and regional facility staff made presentations to 3,765 students in 41 schools during the 2017-2018 school year. 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. 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 468 Twitter followers, up from 420 Twitter followers at the end of 2017, and 1,016 "Total Page Likes" on Facebook, up from 685 in 2017.

MMCD currently uses the service "GovDelivery" to give advance notification to District residents of adult mosquito treatments. In 2018, GovDelivery changed its name to "Granicus" and continued to manage MMCD's direct treatment notification email lists. MMCD also works with Granicus to make efficient use of social media to reach people who are interested in finding out more about District treatment activities. Granicus is also used to distribute press releases and make announcements about job openings. Our GovDelivery subscriptions continue to experience robust growth. 2018 ended with 7,407 distinct subscribers to our email notification lists, up from 4,879 subscribers in 2017. This is up from 4,129 in 2016, 3,177 in 2015, and 2,503 in 2014.

Sustainability Initiative

MMCD's Sustainability Initiative began in 2013 with a steering group assembled to set up a framework for incorporating sustainability principles into the organization. Since then the group evolved into a standing team and workgroups have implemented many new measures to enhance sustainability initiatives in the areas described below. The Sustainability Team's overarching theme is to document current sustainability efforts and to examine the economic, environmental, and social impacts of sustainability on the District going forward.

This group focuses on five opportunity areas: 1) reducing energy usage; 2) reducing waste; 3) identifying and using renewable resources; 4) promoting social responsibility and the health and wellness of our employees; and 5) compiling a guiding document, or Annual Report. In 2017, an additional area was added to focus on increasing the culture of sustainability.

Reducing Energy Usage The Reducing Energy Usage group focused on reducing MMCD's overall energy consumption, specifically by reviewing MMCD electricity and fuel consumption and considering ways to reduce energy usage. Between 2013 and 2018 the group worked to reduce both electricity and fuel consumption. We compared forecasted and actual energy and fuel savings to evaluate improvements we achieved. Between 2016 and 2018 we concentrated on electricity used by computers and integrating more fuel-efficient vehicles into our fleet.

Reducing Waste 2018 was another successful year for all facilities. Composting became the norm throughout the District with all facilities reporting the widespread use of composting organic material. Facilities used the compost in various ways such as gardens and prairie restoration projects. Three facilities reduced their paper towel waste by converting to personal re-usable hand towels in their restrooms. Other facilities began composting their paper towels. Also new in 2018 was plastic bag recycling receptacles in our facilities.

Renewable Energy The "Renewable Energy" group continued to expand their knowledge on regional renewable energy projects. In 2018, the team continued to focus on solar energy, local solar groups, and projects in the metro area. Six of our seven facilities are signed up to receive electricity starting in 2019 from a "Sunscription" with US Solar solar gardens in a program that will also reduce our electricity cost.

Social Responsibility and Wellness This area includes how we give back to and take care of our community. In 2018, we held our 5th annual shoe drive, donated to our summer food shelf drive, and continued prairie plantings and vegetable gardens. Plans for 2019 include continuing these programs while looking for new ways to enhance the health and wellbeing of our employees.

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 association again in 2018 and Carey LaMere maintains the association's web site, http://www.nabfa-blackfly.org.

North Central Mosquito Control Association Mark Smith and Sandy Brogren served 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 2018 meeting was held in Winnipeg, and eight MMCD staff attended and visited the labs and field headquarters of Winnipeg's mosquito control program, discussing the many similar challenges faced in both regions. The meeting qualified attendees for pesticide applicator re-certification for MN and ND. MMCD will host the 2019 meeting 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 attend a variety of scientific meetings throughout the year. Following is a list of papers and posters presented during 2018 and talks that are planned in 2019. MMCD specimens and data were also used in the following:

Bennett, Steve Woodrow. 2017. The Complex Eco-Epidemiology of Tick Borne Disease: Ticks, Hosts and Pathobiomes in an Urbanizing Environment - A Dissertation Submitted To The Faculty Of University Of Minnesota August 2017. Available at http://hdl.handle.net/11299/191397

2018 Presentations & Posters

Johnson, K. 2018. Efficacy trials of Sumilarv 0.5G in St. Paul, Minnesota catch basins. Presentation: Michigan Mosquito Control Association Annual Meeting in Lansing, MI, and American Mosquito Control Association Meeting in Kansas City, MO.

Kirkman, M. 2018. *Coquillettidia perturbans* in the cattail marshes of Minneapolis. Presentation: North Central Mosquito Control Association Annual Meeting in Winnipeg, Manitoba.

Manweiler, S. 2018. Controlling *Coquillettidia perturbans* in rooted and floating cattail sites with VectoLex FG. Presentation: Michigan Mosquito Control Association Annual Meeting in Lansing, MI.

Manweiler, S. 2018. The quest for season-long catch basin control. Presentation: North Central Mosquito Control Association Annual Meeting in Winnipeg, Manitoba.

Read, N. and K. Johnson 2018. Mosquitoes, people, virus – putting together a risk reduction strategy for Jamestown Canyon illness. Minnesota GIS/LIS Consortium Annual Meeting in Duluth, MN.

Smith, M. 2018. Capturing innovative ideas – how the Metropolitan Mosquito Control District is striving to improve. Presentation: American Mosquito Control Association Meeting in Kansas City, MO.

Walz J. 2018. MMCD Black Fly Control Program update. Presentation: North American Black Fly Association Meeting in Athens, GA.

2019 Presentations & Posters

Larson, S. 2019. The role of diet on the attractiveness of human hosts to mosquitoes. Presentation: Michigan Mosquito Control Association Annual Meeting in Lansing, MI.

Manweiler, S. 2019. Mosquito control and the Endangered Species Act. Presentation: Michigan Mosquito Control Association Annual Meeting in Lansing, MI.

Read, N. 2019. Drone-based photography for finding cattail mosquito habitat. Presentation: American Mosquito Control Association Meeting in Orlando, FL.

Smith, M. 2019. The importance of connection – government organizations and private companies working together in the mosquito control industry. Presentation: American Mosquito Control Association Meeting in Orlando, FL.

Smith, M. 2019. Creation of a temporary positive pressure spray booth and utilizing a Malvern Spraytec laser to improve mosquito control applications. Presentation: American Mosquito Control Association Meeting in Orlando, FL.

Soukup, A. 2019. Boots on the ground: a look into a season with MMCD's field staff. Presentation: American Mosquito Control Association Meeting in Orlando, FL.

APPENDICES

Appendix A	Mosquito and Black Fly Biology and Species List
Appendix B	Average Number of Common Mosquito Species Collected per Night in Four New Jersey Light Traps 1965-2018
Appendix C	Description of Control Materials
Appendix D	2018 Control Materials: Percent Active Ingredient (AI), AI Identity, Per Acre Dosage, AI Applied Per Acre and Field Life
Appendix E	Acres Treated with Control Materials Used by MMCD for Mosquito and Black Fly Control for 2010-2018
Appendix F	Graphs of Larvicide, Adulticide, and ULV Fog Treatment Acres, 1984-2018
Appendix G	Control Material Labels (separate attachment)

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 (spring *Aedes*), summer floodwater species (summer *Aedes*), the cattail mosquito, permanent water species, 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 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.

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. MMCD uses gravid traps to monitor *Cx. pipiens* and *Cx. restuans*.

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 (15 species in the District) 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 net) or CO_2-baited trapping is recommended.

Summer Floodwater *Aedes* Eggs of summer floodwater *Aedes* (5 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 common 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.

***Psorophora* Species** Larvae of this genus develop in floodwater areas. The adults will feed on humans. Numerous viruses have been isolated from species in this genus, however, there is no confirmation that these species transmit pathogens that cause human disease in the District. Four species occur here: *Psorophora 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 *P. ciliata* is the largest mosquito found in the District, and its larvae are predacious and even cannibalistic, feeding on other mosquito larvae.

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 as well as *Uranotaenia sapphirina.* These mosquitoes are multi-brooded and lay their eggs in rafts on the surface of the water. Adults prefer to feed on birds or livestock but will bite humans (except for *Ur. sapphirina* which feeds exclusively on annelids and *Cx. territans* which feeds on amphibians and snakes). They overwinter in places like caves, hollow logs, stumps or buildings.

Invasive or Rare Species

Orthopodomyia signifera is a container-breeding mosquito that is rarely encountered in collections made by MMCD. *Aedes albopictus*, the Asian tiger mosquito, is an invasive species that likely cannot overwinter in the District and is reintroduced into the district each year.

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, South Fork 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

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 can 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. 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.

Non-Targeted Species

Simulium vittatum develops in a wide range of flowing waters from small streams to large rivers. Larvae are tolerant of extreme temperatures, low oxygen, pollution and a wide range of current velocities. It is not targeted for treatment, because adults are not known to bite humans. Hosts include large mammals such as horse and cattle.

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*	rare
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, 1965-2018. Trap 1, Trap 9, Trap 13, and Trap 16 have run yearly since 1965. Trap 1 was discontinued in 2015.

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	0.01	0.03	0.01	1.65	24.53	0.06	4.80	33.44	27.76
2017	0.01	0.08	0.09	0.17	25.71	0.05	9.62	37.85	22.27
2018	0.02	0.04	0.18	0.26	15.21	0.05	1.88	20.76	22.54

*Trap 1 discontinued in 2015 due to operator retirement; averages after 2014 are from three traps used since 1965: Trap 9, Trap 13, and Trap 16.

APPENDIX C Description of Control Materials Used by MMCD in 2018

The following is an explanation of the control materials currently used by MMCD. The specific names of products used in 2017 are given. The generic products will not change in 2019, 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.

Bacillus thuringiensis israelensis **(Bti) & methoprene granules** Valent BioSciences
VectoPrime® FG EPA# 73049-501

VectoPrime is a new corncob formulation containing methoprene and *Bti*. VectoPrime corn cob may be applied in all types of larval habitat. The duplex material controls existing larvae with *Bti* and has a seven-day residual control duration with methoprene. This residual control activity allows staff to work in other areas if additional rains immediately reflooded the site. Another possible advantage is that it may be effective to control late fourth instar larvae. These larvae slow their feeding activity as they get ready to pupate and therefore are less susceptible to *Bti*. According to the manufacturer, the reintroduction of juvenile hormone stimulates new feeding activity in later fourth instars causing them to ingest more *Bti*. Additionally, the methoprene can disrupt metamorphosis and thereby kill mosquito pupae. This material can be applied at 4 lb per acre (0.2428 lb/acre *Bti* and 0.0040 lb/acre methoprene). In evaluations, the material is applied to pockety sites with cyclone seeders or power backpacks.

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

Natular is a new formulation of spinosad, a biological toxin extracted from the soil bacterium *Saccharopolyspora spinosa*, 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 spinosa,* 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.

Pyrethrin Adulticides

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.

Pyrethroid Adulticides

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]).

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.

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).

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. This material has been phased out as the product label was not renewed with the EPA. The cost of the re-registration process and required testing made the product economically unviable for the limited mosquito control market.

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 rates of 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.

APPENDIX D 2018 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 (lb)	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
			9 lb	0.0450	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
VectoPrime® FG**	*Bti* and methoprene	6.07 *Bti* 0.10 methoprene	4 lb	0.2428 *Bti* 0.0040 methoprene	7 single flood
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.
**Experimental

APPENDIX E **Acres Treated with Control Materials Used by MMCD for Mosquito and Black Fly Control, 2010-2018.The actual geographic area treated is smaller because some sites are treated more than once**

Control Material	2010	2011	2012	2013	2014	2015	2016	2017	2018
Larvicides									
Altosid® XR Briquet 150-day	174	205	165	189	193	186	168	166	167
Altosid® XRG	9,924	13,336	23,436	6,948	52	0	0	0	0
Altosid® Pellets 30-day	36,516	30,749	13,172	15,813	26,179	31,494	19,173	17,939	10,202
Altosid® Pellets catch basins (count)	227,611	234,033	226,934	246,300	239,829	248,599	240,806	252,694	262,851
MetaLarv™ S-PT	0	0	2,750	14,063	18,073	21,126	33,409	23,740	23,574
Natular™ G30	0	0	9,524	15,000	14,950	8,840	13,023	12,271	15,662
Altosid® XR Briquet catch basins (count)	0	0	458	375	437	450	448	445	509
VectoLex® FG granules	0	0	0	2,330	3,064	3,777	6,076	4,773	4,660
VectoMax® CG granules	0	0	0	0	0	0	0	0	0
VectoBac® G *Bti* corn cob granules	250,478	201,957	207,827	150,280	255,916	258,148	234,120	136,173	134,926
VectoBac® 12 AS *Bti* liquid (gal used) Black fly control	2,630	3,817	3,097	3,878	4,349	4,351	3,112	3,621	3,234
Adulticides									
Permethrin 57% OS Permethrin	8,826	7,544	8,578	9,020	8,887	6,093	8,128	5,038	3,771
Scourge® 4+12 Resmethrin/PBO	27,794	24,605	8,078	37,204	44,890	19,767	23,072	2,090	0
Anvil® 2 + 2 Sumithrin/PBO	26,429	29,208	27,486	36,000	31,381	27,183	16,399	11,683	7,790
Pyrenone® Adulticide	2,560	0	0	0	0	0	0	0	0
Pyrocide® Adulticide	0	0	0	0	5,338	3,605	0	0	0
Zenivex® Etofenprox	0	0	0	0	0	10,380	34,984	23,097	26,918

APPENDIX F Graphs of Larvicide, Adulticide, and ULV Fog Treatment Acres, 1984-2018

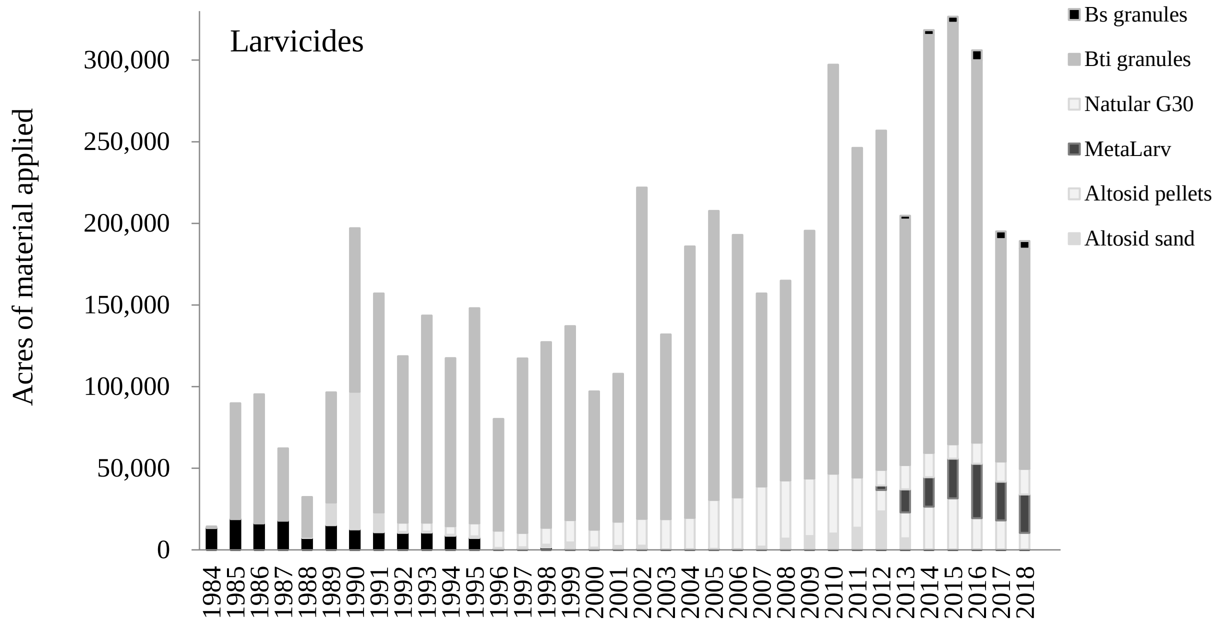

Figure F.1 Summary of total acres of larvicide treatments applied per year since 1984. For materials that are applied to the same site more than once per year, actual geographic acreage treated is less than that shown.

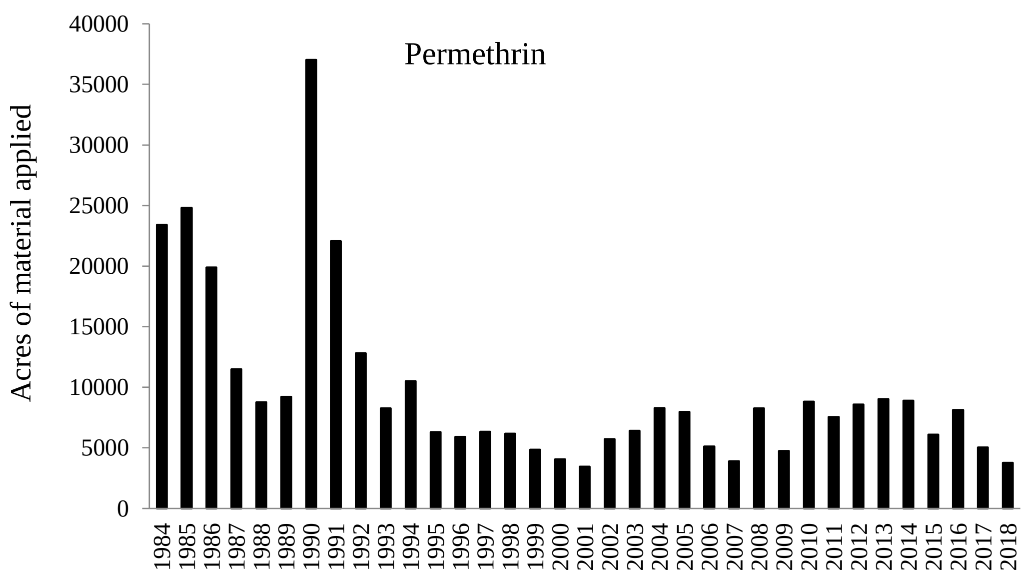

Figure F.2 Summary of total acres of permethrin treatments applied per year since 1984. This material may be applied to the same site more than once per year, so actual geographic acreage treated is less than that shown.

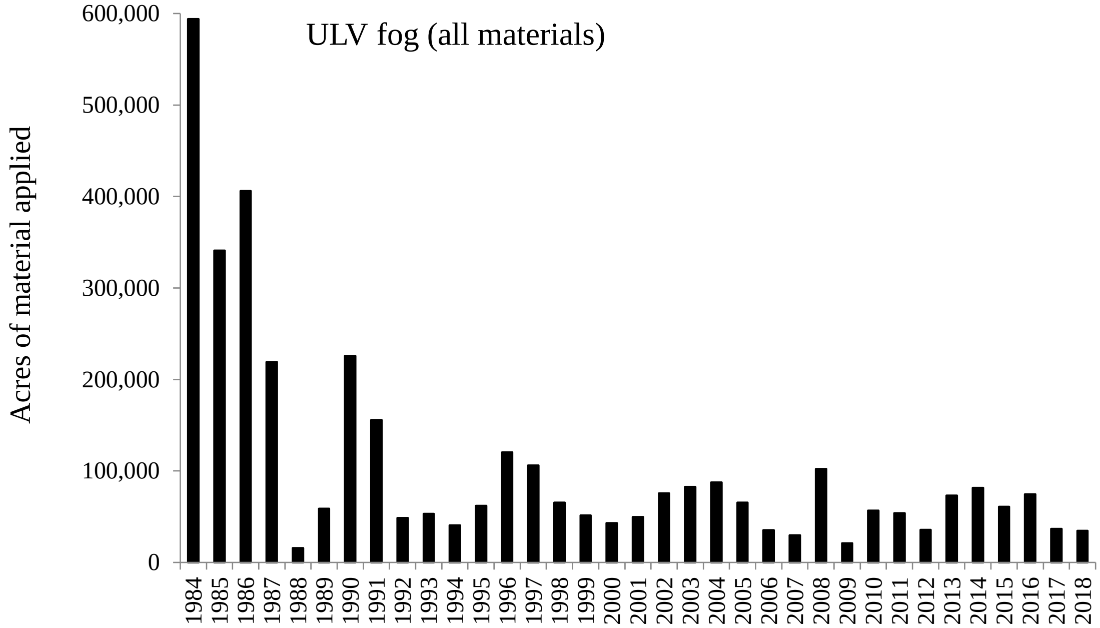

Figure F.3 Summary of total acres of ULV fog treatments applied per year since 1984. These materials may be applied to the same site more than once per year, so actual geographic acreage treated is less than that shown.

APPENDIX G Control Material Labels

Altosid® XR Extended Residual Briquets (EPA# 2724-421)

Altosid® Pellets (EPA# 2724-448)

MetaLarv® S-PT (EPA# 73049-475)

VectoBac® 12AS (EPA# 73049-38)

VectoBac® G (EPA# 73049-10)

VectoLex® CG (EPA# 73049-20)

Natular™ G (EPA# 8329-80)

Natular™ G30 (EPA# 8329-83)

Permethrin 57% OS (EPA# 8329-44)

Pyrocide® Mosquito Adulticiding Concentrate 7369 (EPA#1021-1569)

Onslaught® FastCap (EPA# 1021-1815)

Scourge® 4+12 (EPA# 432-716)

Anvil® 2+2 ULV (EPA# 1021-167-8329)

Zenivex® E4 RTU (EPA# 2724-807)

Merus™ 2.0 RTU (EPA# 8329-94)

Appendix H MMCD Technical Advisory Board Meeting February 13, 2019

TAB Members Present:

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

MMCD Staff in Attendance: Stephen Manweiler, Nancy Read, Diann Crane, Scott Helling-Christy, Scott Larson, Kirk Johnson, Carey LaMere, Mike McLean, Mark Smith, John Walz, Jennifer Crites, Paul Youngstrom

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

(Initials in the notes below designate discussion participants)

Welcome and Call to Order

Chair Christine Wicks called the meeting to order at 12:30 p.m., reminded the TAB of their charge to review the program, and suggested that participants keep in mind possible resolutions. All present introduced themselves. Christine then called on MMCD staff for their presentations.

2018 Season Overview

Diann Crane described the categories of mosquitoes found in the District and their biologies. The year 2018 was marked by a very late spring but quick warm-up in late May. Spring *Aedes* and cattail mosquito adult numbers were close to average, while *Aedes vexans* had a particularly high peak around July 4th. The cattail mosquito population model accurately predicted that populations would be lower in 2018 than the record high observed in 2017, and predicts another decline for 2019.

GM – You have 4 NJ light traps, what information do you really get from those compared with other sampling methods? Are they worth the effort? DC – We struggle with that question as well, we kept only those traps that have been present for a very long time and provide a long-term trend.

Spring *Aedes*

Nancy Read described the species that make up MMCD's "spring *Aedes*" group in more detail, and presented data on the seasonality of larval abundance for the various species. In 2017, as part of our cost-cutting measures, we eliminated spring *Aedes* treatments in the outer, less populated area of the District (priority 2 area, "P2"). At last year's meeting, TAB members raised concerns about Jamestown Canyon virus and the possible role of spring *Aedes* as vectors. In 2018, we pushed larval surveillance and treatments into parts of P2 where there were significant human populations and where we could find some history of larval production. In the past, we have used a lower larval count threshold for treatment for spring *Aedes* because the larvae are difficult to catch and the adults have a longer lifespan than regular summer species such as *Ae. vexans*. This was simply applied by date, given that usually spring-group larvae are found for several weeks before summer-group larvae. However, with the late spring in 2018, larvae of the spring *Aedes* group were found at the same time as larvae of *Ae. vexans*, so in order to more accurately apply a spring *Aedes* threshold the lab identified larvae to "*vexans* / non-*vexans*" in samples to determine treatments for aerial treatment sites. We raised the spring *Aedes* P1 threshold to 1 per dip (up from the previous 0.5 per dip) because of the extremely low numbers of adults that have been found in P1, and used savings from that to enable more work in P2 where spring *Aedes* populations have been much higher. In 2019, we plan to continue using 1 per dip in both P1 and selected P2 areas.

DN – The majority of human JCV cases reported in recent years have been from Wisconsin and Minnesota. This is partially due to increased surveillance efforts by our respective health departments. We're looking harder, so we're finding more cases. In particular, the MDH Public Health laboratory developed an antibody test for the virus, and we are encouraging medical providers to submit specimens from suspect cases. We are also confirming our test results with CDC. Wisconsin has not yet developed a test of their own. However, they are sending specimens directly to CDC for testing. We'd suspect many more reported cases nationwide if other states increased their surveillance efforts too.

Black Fly

John Walz reported on the black fly situation in 2018. There were a few times when treatments were not done on the Minnesota River because of flooding. The nontarget sampling is continuing to show no problems from treatment. We received an unusually high number of customer calls, especially around Minnehaha Creek, and there was some news coverage about black fly problems, we will follow up on those locations in 2019. Another unusual event was our staff rescued a woman from the Minnesota River.

RS – Is there a particular role that black flies play in ecological systems? JW – Larvae are food for trout, we don't treat trout streams. On large rivers we do not try for eradication but rather for reducing adult populations to tolerable levels.

West Nile Virus in 2018

Kirk Johnson described that 2018 was an active year for West Nile virus, in both western areas where the primary vector is *Cx. tarsalis*, and in eastern areas where the primary vector is *Cx. pipiens*. MMCD had a record number of positive WNV mosquito samples (132 out of 842 samples), and more *Cx. pipiens* positive. We have in the past been on the northern edge of the *Cx. pipiens* range but is seems like we are seeing them more frequently in recent years. The pattern of human cases included early and late occurrences, which matched the early and late infections seen in *Cx. pipiens*, while the main peak in human cases matched *Cx. tarsalis* infection rates. This may indicate that the Twin Cities transmission may be starting to behave more like Chicago where large numbers of cases may be related to *Cx. pipiens* populations, while still having much of the transmission related to *Cx. tarsalis*. We plan on taking steps in 2019 to make sure that St. Paul catch basins are treated often enough to reduce disease risk from *Cx. pipiens.* We will also test additional larvicides (Altosid P35 and VectoLex) for use in catch basins. We are adding more traps to our gravid trap network as well to improve coverage.

RS – It's very important to control vectors and have people protect themselves. How does the mosquito pick up the virus? KJ – Mosquitoes pick it up from birds, both *tarsalis* and *pipiens* bite both birds and mammals, virus overwinters most likely in mosquitoes.
DN – MMCD has a great data set from weekly sweep collections, historically more *tarsalis* than *pipiens* in sweeps, is that changing? KJ – yes in sweeps we were starting to pick up more *pipiens* and *pipiens/restuans,* concern regarding disease transmission.

Break for pie

Longhorn Tick
MDH representative Dave Neitzel briefed the TAB on the new invasive longhorn tick (and had shared "Multistate Infestation with the Exotic Disease-Vector Tick *Haemaphysalis longicornis* - United States, August 2017-September 2018" by Beard et al. from Morbidity and Mortality Weekly Report 67(47):1311-1313, Nov. 30, 2018). This tick species has been moved on livestock, and was blocked at some quarantine stations but then found on sheep in NJ in 2017 (plus scattered prior archival records). It can reproduce quickly, seems to be spreading rapidly, and there is concern about possible vector capacity. MDH is working with MN Board of Animal Health, MnDNR, and veterinarian outreach groups to encourage people to turn in unusual tick specimens. Dave has also checked MN archive of related ticks and did not find any longhorn ticks. A new key is available to help with identification (Dave sent to MMCD). Dave stressed it is important to keep lines of communication open.
JM – What is cold-hardiness of this species? DN – Recent habitat modeling paper suggests Minneapolis-St. Paul area is at northern edge of potential range.
NR – If found, what do we do? DN – If livestock producer, may be possible to do localized control. In eastern US, have not been successful efforts to eradicate. JW, CL – We heard about localized control efforts in NJ from Tadhgh Rainey who works there. DN – Can use permethrin, plus some livestock treatments.
CL – MMCD will be getting reference specimens, will share with DN.
RS – Might this be a situation suitable for a gene-drive kind of solution? DN – haven't heard of anyone trying that yet.

Ticks at MMCD Update
Kirk Johnson presented for Janet Jarnefeld who could not attend on this date. We found continued high numbers of *Ixodes scapularis* in our sampling in 2018. MMCD is working with MDH on surveillance for longhorn ticks both from our trapping and from field staff encounters. We will be updating our tick identification card to include longhorn and lone star invasive ticks. We continue to use social media to get the word out about ticks.

Bees and Endangered Species Act

Stephen Manweiler reviewed the Endangered Species Act process and how we worked with the Fish and Wildlife Service (Andrew Horton) on an informal consultation about MMCD activities and the rusty patched bumble bee. He described the habitat and seasonal biology of the bee. The nesting habitat is typically below ground in open areas. The bees also need floral resources, and overwintering queens need leaf litter sites. Looking at the larval control program, there did not seem to be any significant risk to the bees. Adulticides could have some effect if there is spatial and temporal overlap with the bees. A number of areas within the metro are designated as high probability zones for rusty patched bumble bee. MMCD makes 3 kinds of treatments. For permethrin barrier sprays, we target wooded area edges and avoid flowering plants. Small scale harborage ULV treatment targets wooded areas with few blooming plants, and active ingredients degrade quickly. Wide-area ULV fog treatments are made after sunset, when bees are expected to be in their nests, not likely to be affected. The conclusion from the informal consultation was that exposure of this endangered species to mosquito control actions is unlikely due to minimal overlap with mosquito control activities. MMCD records showed there were relatively few adulticide treatments in high probability bee habitat areas and the adulticides covered minimal areas.

GM – Is this written up as a document somehow? Folks working with pollinators at DNR dealing with similar issues regarding RPBB would be interested
SM – If that would be helpful, we could put a document together. JM – Would be very helpful for communicating with local pollinator groups.
PM – If there has been testing of pyrethroids on related species that would be helpful, gives order of magnitude for exposure. SM – We considered some of that, process emphasizes exposure first so did not go into as much detail. Honey bee data might be of interest anyway.
CS – Would be good to get write-up, also potential bee range maps change every 6 months. Males do not go back to the nest so consider exposure to them. VS – Andrew is based in office next to ours in MN, we consult with him a lot.

Drone Update

Scott Larson described some basics about drone technology, how they are regulated and general uses. Worldwide, drones are starting to be used in mosquito control for surveillance and for insecticide application. At MMCD we started to explore drone technology and a group is training to get Remote Pilot licenses. We purchased two drones with cameras to gain experience and test uses for surveillance. Drone imagery has been a useful adjunct to update aerial imagery and look in more detail at wetland sites. We are hoping to apply for FAA approval for insecticide applications for the future.

CW – What other agencies are using drones? JM – We use a little, if MMCD wants to use in Three Rivers Parks, ask us for a permit. VS – Just starting to use ourselves, but not legal for others on federal lands.
JM – Can you use photos in your GIS? NR – Yes.
PC – Can you use beyond line of sight? SL – Not now, but there are rule changes coming.
CS – At MnDOT using primarily for bridge inspections.
CW – For pesticide application, no state regulation yet other than having an Aerial Applicator license, and products would need to be labeled for aerial application, besides FAA and other

regs. Wisconsin is working on updated rules. Maine is trying to control marmorated stink bug using drones so more motivation for changing rules. Important conversation to have.

Emerging Technologies

Stephen provided information in response to the TAB request about gene drive and Crispr-cass9. Much of this work is related to sterile male insect release, which has been used historically, but there are now new methods to make this quicker and easier to do. He described a system using the *Wolbachia* bacterium-based sterile male incompatibility in a program called "Debug Fresno" to successfully reduce *Ae. aegypti* vector populations in Fresno CA. The company Oxitec has been testing transgenic *Ae. aegypti* in Grand Cayman and in Brazil and achieved significant control. So far research has focused on malaria vectors (*Anopheles*) and *Ae. aegypti*, and there has been some interest in control of *Ae. albopictus*. We have not considered it here because the mosquitoes tested so far have not been major issues here, the expense is considerable, and there are still risks to be addressed.

There were no further questions from the TAB about the overviews.

Discussion and Resolutions

Chair Christine Wicks discussed the procedure for resolutions and asked TAB members what they would like to put forward to communicate with the MMCD Commissioners. The following were drafted by TAB members, discussed, and voted on.

RESOLUTION: The TAB supports the program presented in the 2017 Operational Review and 2018 Plan and acknowledges the efforts of the MMCD staff on its presentation.
Motion to approve made by JM
Second - RS
Motion passed without dissent.

RESOLUTION: The TAB commends MMCD on its review of the Endangered Species Act and its impact on MMCD activities. The review of the rusty patched bumble bee biology and distribution in relation to current mosquito control operations showed low risk to the bees. MMCD should stay in contact with the USFWS to keep its high potential zone map up to date and be aware of new USFWS guidance regarding this species, and to stay informed of any new listed species in the District that might be impacted by operations.
Motion to approve made by RS
Second - GM
Motion passed without dissent.

RESOLUTION: That the MMCD produce written documentation detailing the informal consultation with USFWS on potential impacts of mosquito control operations on the rusty patched bumble bee, in consultation with USFWS staff, and that this be made available to the public.
Motion to approve made by JM
Second - PM
Motion passed without dissent.

RESOLUTION: The TAB commends MMCD on evaluating the potential importance of *Cx. pipiens* as a human West Nile virus vector locally, and encourages continued evaluation of this species.
Motion to approve made by PM
Second - BS
Motion passed without dissent.

There being no further discussion, the TAB adjourned at 3:40 p.m.

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 Vision

To be the leading mosquito abatement district in the world

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

Our Values

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

mmcd
METROPOLITAN MOSQUITO CONTROL DISTRICT

Editorial Staff & Contributors

Diann Crane
Scott Larson
Carey LaMere

The following people wrote or reviewed major portions of this document:
Janet Jarnefeld, Kirk Johnson, Carey LaMere, Scott Larson, Stephen Manweiler, Mike McLean, Nancy Read, Ken Simmons, Mark Smith, and *John Walz*

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