METROPOLITAN MOSQUITO CONTROL DISTRICT
2020 OPERATIONAL REVIEW & PLANS FOR 2021

Annual Report to the Technical Advisory Board

Joe Elling, Field Operations Supervisor, Plymouth Facility, testing larvicide treatments by drone in a small wetland. MMCD photo

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 2021

Jeff Reinert	Anoka County
Scott Schulte	Anoka County
Robyn West	Anoka County
Gayle Degler	Carver County
Tom Workman	Carver County
Mary Hamann-Roland	Dakota County
Laurie Halvorson	Dakota County
Liz Workman	Dakota County
Kevin Anderson	Hennepin County
Angela Conley	Hennepin County
Chris LaTondresse	Hennepin County
Jim McDonough	Ramsey County
Mary Jo McGuire	Ramsey County
Rafael Ortega	Ramsey County
Michael Beard	Scott County
Dave Beer	Scott County
Gary Kriesel	Washington Co.
Lisa Weik	Washington Co.

Technical Advisory Board

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

Technical Advisory Board Members 2020-2021

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Phil Monson	Mn Pollution Control Agency
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Robert Sherman	Independent Statistician
Vicki Sherry	US Fish & Wildlife Service
Christopher Smith	Mn Dept. of Transportation
Christine Wicks	Mn Dept. of Agriculture

Metropolitan Mosquito Control District Contributing Staff

Stephen Manweiler	Executive Director
Diann Crane	Entomologist
Janet Jarnefeld	Technical Services/Tick
Kirk Johnson	Vector Ecologist
Carey LaMere	Technical Services/Black Fly
Scott Larson	Assistant Entomologist
Alex Carlson	Public Affairs
Nancy Read	Technical Services Coordinator
Mark Smith	Purchasing Lead
John Walz	Technical Services/Black Fly

METROPOLITAN MOSQUITO CONTROL DISTRICT

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Metro Counties Government Center
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April 28, 2021

Dear Reader:

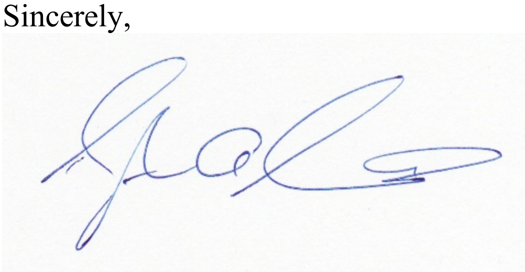
The following report is the Metropolitan Mosquito Control District's (MMCD) 2020 Operational Review and Plans for 2021. It outlines program operations based on the policies set forth by the Metropolitan Mosquito Control Commission (MMCC), MMCD's governing board of elected county commissioners.

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 11, 2021 are included in this report.

TAB's recommendations and report were accepted by the Commission at their April 28, 2021 meeting. The Commission approved the MMCD 2020 Operational Review and Plans for 2021 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

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April 1, 2021

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

Dear Commissioner Conley,

The Technical Advisory Board (TAB) met on February 11, 2021 to review and discuss MMCD operations in 2020 and plans for 2021. 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 commends the MMCD staff and management on their efforts to maintain operations and budget in consideration of COVID-19 restrictions and needs, without interruption in services.

2. The TAB recognizes MMCD's current efforts to minimize nontarget impacts associated with adulticides and recommends that MMCD staff follow USFWS monarch butterfly threatened or endangered species listing discussions, as well as review current research and past incidents, to minimize further non-target impacts.

3. The TAB supports the program presented in the 2020 Operational Review and 2021 Plan and acknowledges and appreciates the efforts of the MMCD staff on its presentation.

Sincerely,

Stephen Kells, Professor
Chair, Technical Advisory Board
University of Minnesota, Department of Entomology

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APPENDICES

Executive Summary

The Metropolitan Mosquito Control District (MMCD or the District) strives to provide cost-effective service in an environmentally sound manner. This report presents MMCD staff efforts to accomplish that goal during 2020 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 2021 as we continue to provide an integrated mosquito management program for the benefit of metro area citizens.

COVID-19 Impact on Operations

2020 was dominated by the COVID-19 pandemic and the various challenges it has caused to state and local agencies like MMCD. We were able to adapt our operations to allow for social distancing and other CDC recommendations and were able to conduct our inspections and field work with limited interruption. However, we hired fewer seasonal staff to ensure only one employee per truck, the result being fewer larval samples taken and less adulticiding given the person-hours available. Additionally, a shortage of N95 masks, required for one of our larval control materials, also affected our choice of control strategies.

Mosquito Surveillance

Weather and mosquito production are inextricably linked, and in 2020 there were several events that factored into the timing and emergence of mosquito populations. Warm temperatures at the end of February and the beginning of March melted much of the snowpack. However, for the third year running, an April snowstorm dumped heavy snow which brought the season snowfall total to 42.9 inches, which was 11.2 inches below average. There were three large broods and eleven small- to medium-sized broods in 2020; the last brood developed from very localized rains at the beginning of September.

Adult spring *Aedes* emerged May 27 and peaked June 1. Summer *Aedes* had two large peaks, June 7 and July 13, although at levels below the 20-yr average. Given the high water levels in cattail habitats in the fall of 2019, *Coquillettidia perturbans* populations were higher than average. Adult *Cq. perturbans* emerged early and peaked on June 30.

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 virus (WNV), and Jamestown Canyon virus (JCV), as well as tick-borne illnesses such as Lyme disease and human anaplasmosis.

Fortunately, there were no mosquito-borne disease cases reported in 2020 in Minnesota. The Minnesota Department of Health (MDH) reported zero cases of WNV, which makes 2020 the first year with no human cases since the disease was first discovered in the state in 2002. Eastern equine encephalitis is a growing concern in Minnesota; there were two positive cases found in deceased horses in Aitkin and Benton counties. There were no human cases of EEE in Minnesota.

The District continued monitoring the distribution of ticks in the metro area. The average number of *I. scapularis* per mammal was 1.42 which is similar to all of our yearly averages from 2000-2018 (range 1.21-1.68), and higher than all of our averages tabulated from 1990-1999 (range 0.09-0.41).

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*), *B. sphaericus*, and the bacterial product spinosad. MMCD applied larvicide to 194,911 acres, which is 18,646 fewer acres than in 2019 (213,587 acres treated). A cumulative total of 276,517 catch basin treatments were made to control WNV vectors. Adulticide treatment acres in 2020 (6,450 acres) were lower than in 2019 when 22,321 acres were treated due to lower mosquito abundance later in the season and maintaining CDC guidelines for physical distancing (i.e., adulticiding using truck-mounted equipment requires two technicians).

We postponed most of our plan to reinstate about one third of the larval control cut in 2017 because of potential levy shortfalls due to COVID-19. Responding to COVID-19 resulted in 16% fewer seasonal hires because each vehicle can accommodate only one person to maintain social distancing. In 2021, if the economic situation permits, we plan to replace up to one third of the larval control cut in 2017 as part of the expenditure reduction steps.

To control black flies in the metro area, MMCD treated 29 small stream sites and made 72 large river treatments with *Bti* when the larval population of the target species met the treatment threshold. The average number of adult black flies per sweep in 2020 was 0.88, which is lower than the 1996-2019 average of 1.29. In May, high adult black fly populations of a small stream species occurred resulting in increased customer calls from certain areas of the District. Adult black fly abundance returned to more tolerable levels after May. We plan to investigate the source of these high adult black fly populations and work towards a solution for 2021.

Product and Equipment Testing

Evaluation of products, equipment, and processes is an important part of our program. In 2019, both 8 and 5 lb/acre dosages of VectoBac® G *Bti* achieved good control of *Ae. vexans* in air sites treated by helicopter. Natular® G (5 lb/acre) effectively controlled *Ae. vexans* in air and ground sites. Altosid® P35, a new granular formulation, effectively controlled *Cq. perturbans* in ground sites at 3 lb/acre verifying 2019 results.

Data Management, Public Information, Sustainability, and New Technologies

MMCD continued to explore how unmanned aircraft systems (drones) can be incorporated into our program. In 2020, we received a Certificate of Waiver or Authorization from the Federal

Aviation Administration to make larvicide treatments from drones and MMCD staff treated 63 sites, including some that resulted in significant cost savings. We also continued our use of drones for aerial photography and site scouting.

Public requests for adult mosquito treatments were down slightly compared to 2019 with the peak coming in early July, which coincides with high mosquito numbers in sweep collections. Due to a lack of public events, MMCD shifted to online educational opportunities and released a series of informational and entertaining videos for schools and the public in 2020.

Sustainability efforts continued to expand and become an integral part of MMCD operations, but due to the COVID-19 pandemic some initiatives were curtailed in 2020. We started 2020 with an employee gathering and food drive, and then moved to socially distanced activities and donations.

Chapter 1 Mosquito Surveillance

2020 Highlights

- Snowfall season total was 42.9 inches, 11.1 inches below normal
- Warm temperatures at the end of February and beginning in March melted much of the snowpack
- For the third year running, an April snowstorm dumped heavy snow (6.6 inches on Easter)
- The major summer *Aedes* brood hatched the week of May 17 when 2-4 inches of rain fell District-wide
- There were two large summer floodwater broods and eleven small to medium broods
- That last brood developed from rains in early September
- Identified 12,832 larval and 8,474 adult samples
- Adult spring *Aedes* emerged May 27 and peaked June 1
- Summer *Aedes* had two large peaks, June 7 and July 13, although at levels below the 20-yr average
- *Cq. perturbans* emerged early and peaked on June 30, at levels higher than the 20-year average
- Predicted catch rate for *Cq. perturbans* for 2020 was 90.2/trap. The actual value was 127.34/trap. The prediction for 2020 is 47.3 per trap

2021 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 pipiens*, *Cx. restuans*, *Cx. salinarius*, and *Cx. tarsalis* (*Culex*4 mosquitoes). 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.

2020 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 are shared with the Minnesota State Climatologist's office for analysis, typically at the end of each month. Currently, 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 (Next Generation Weather 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 – September using historical MMCD rain data and CoCoRaHS gauges. This time period is referred to as the 'mosquito season'. Rainfall during the mosquito season was 20.00 inches, slightly above the 60-year District average of 19.88 inches. However, April rainfall can influence adult emergence in May as well. The average precipitation for the weeks of March 29 through October 3, 2020 was 21.43 inches.

Figure 1.1 shows the weekly rainfall averages experienced from April – September 2020. A large spring storm occurred the last week of March. For the third year running, there was heavy snow in April – 6.6 inches fell on Easter. Average weekly rainfall over the one-inch threshold occurred in only five weeks from May – September. There were five very large rain events: two in May, one in June, one in July, and one in August.

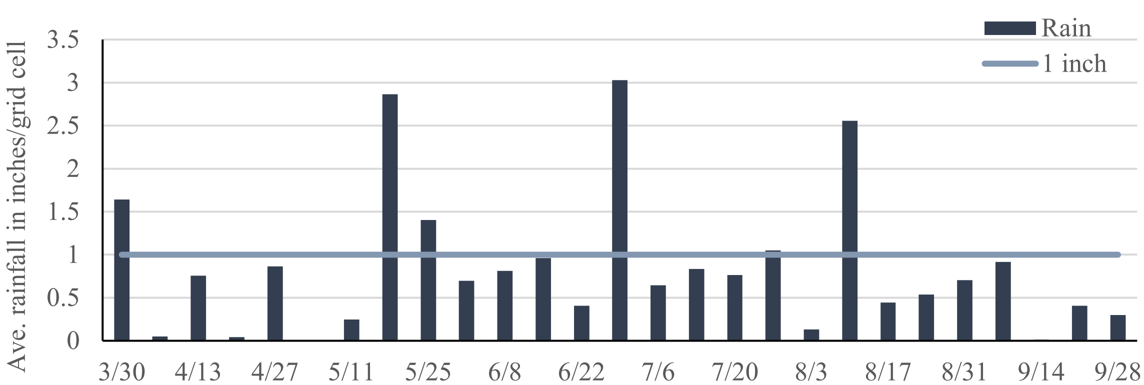


Figure 1.1 Weekly rainfall averages per grid cell, 2020 (RFC data). Dates represent the Monday of each week. Solid line indicates 1-inch, the amount sufficient to induce egg-hatch.

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 2019-2020 was warmer than normal. January and March were both five degrees warmer than normal. Ice-out on Lake Minnetonka occurred April 2. Temperatures in April and May were below normal while June, July, and August were above normal (Figure 1.2).

The snowfall total for the season was 42.9 inches from November-March. The Twin Cities normal monthly snowfall is 54 inches (from 1981-2010). The snowpack began melting from warmer temperatures during the last week of February into March. Precipitation was near normal from January through April, was above normal in May and June, and was below normal for the rest of the mosquito season into the fall (Fig. 1.2).

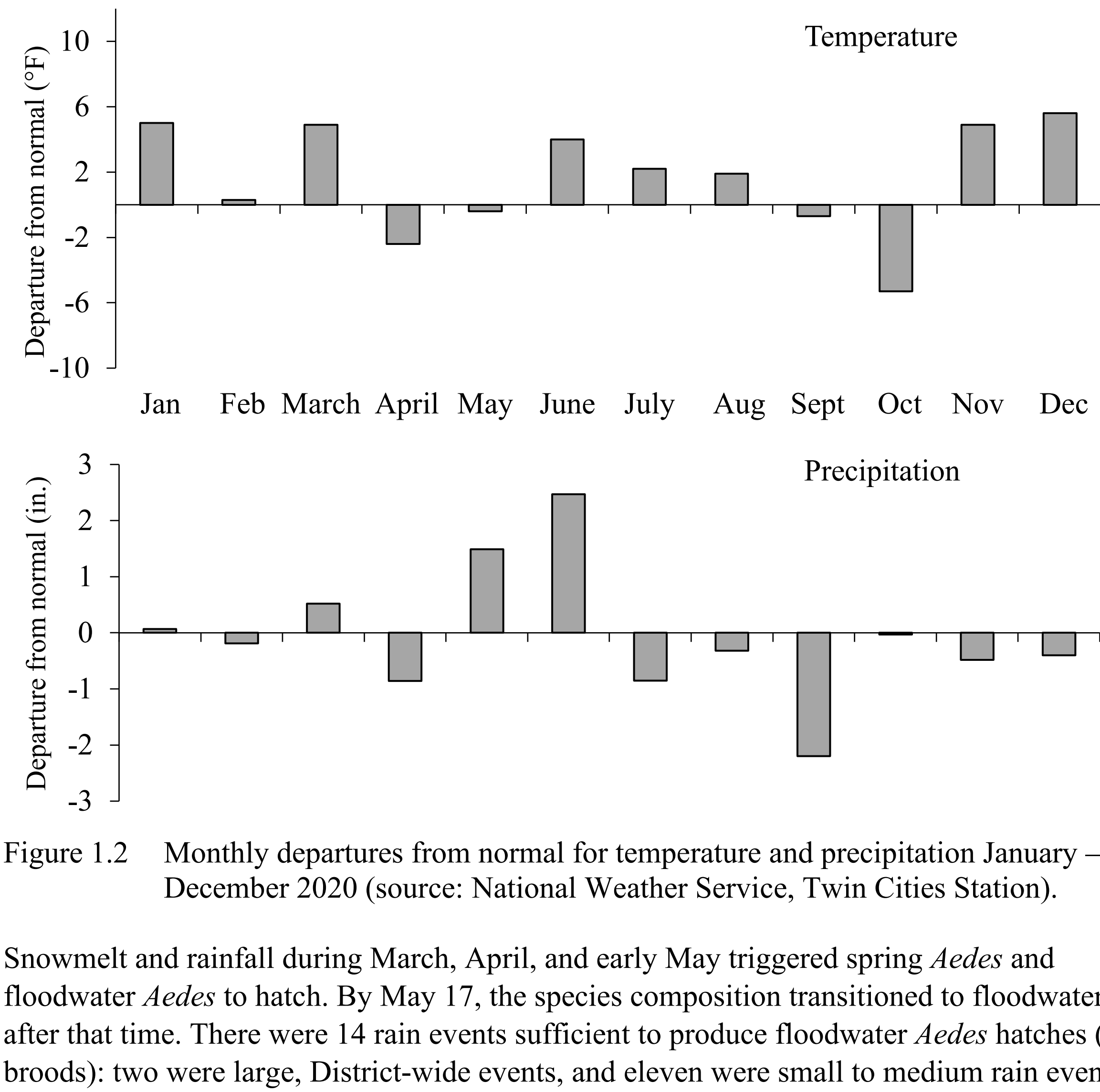


Figure 1.2 Monthly departures from normal for temperature and precipitation January – December 2020 (source: National Weather Service, Twin Cities Station).

Snowmelt and rainfall during March, April, and early May triggered spring *Aedes* and floodwater *Aedes* to hatch. By May 17, the species composition transitioned to floodwater *Aedes*; after that time. There were 14 rain events sufficient to produce floodwater *Aedes* hatches (i.e., broods): two were large, District-wide events, and eleven were small to medium rain events that occurred in localized areas of the District. The amount of area affected by rainfall, the amount of rainfall received, and the resultant amount of mosquito production and acreage treated determines brood size. Figure 1.3 depicts the geographic distribution and magnitude of weekly rainfall received in the District from April – September 2020. 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, enough to initiate a brood.

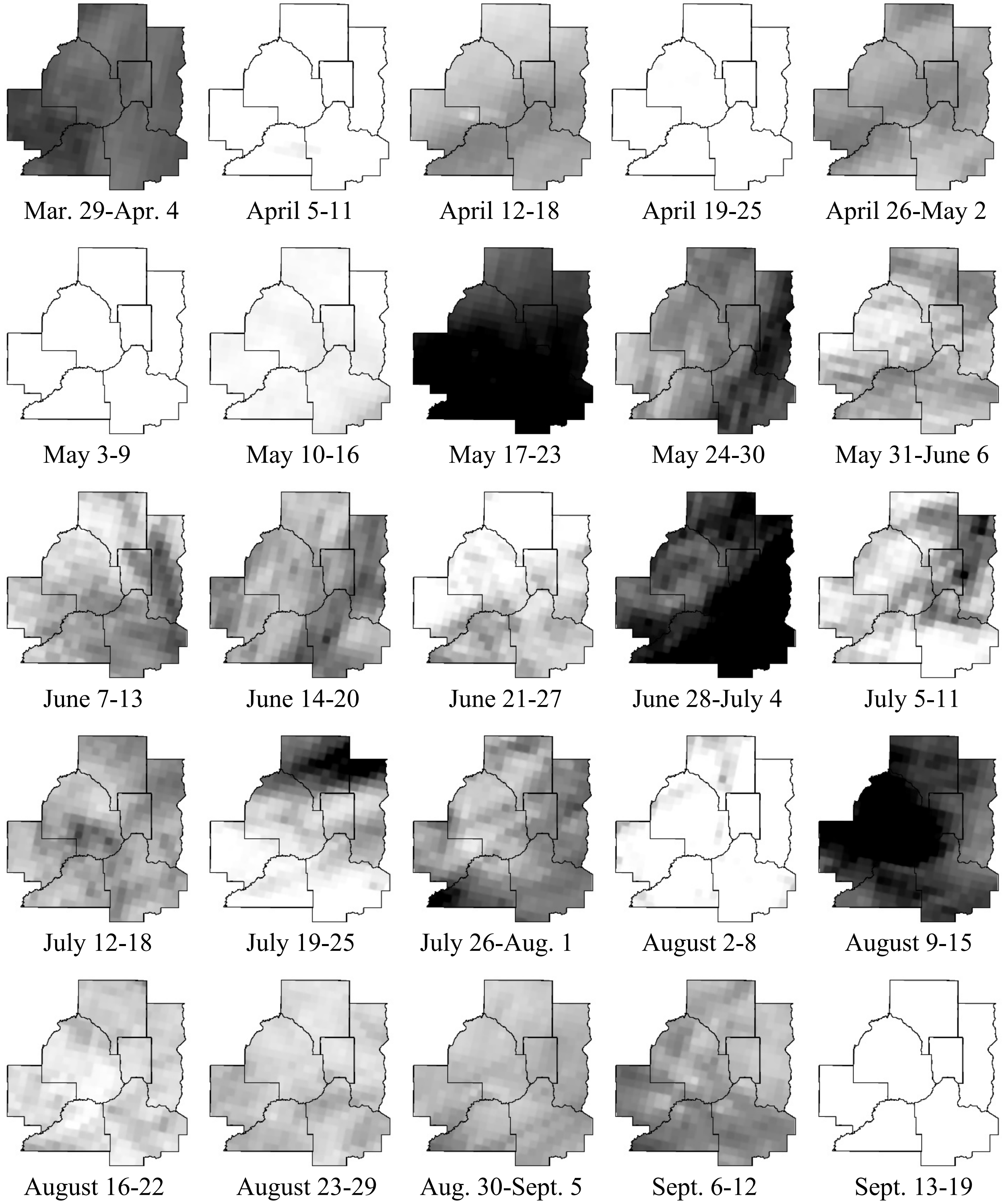
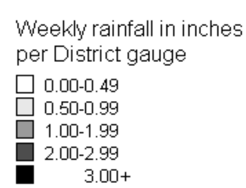


Figure 1.3 Weekly rainfall in inches, 2020. RFC-corrected data using 406 4x4 km grid cells. Inverse distance weighting was the algorithm used for shading of maps.



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 are 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 10 dips is recorded as the number of larvae per dip. Larvae are submitted to MMCD's Entomology Lab for identification.

To expedite sample processing for high priority helicopter treatments (air sites), most larvae are identified to genus only, but again in 2020 we identified the spring *Aedes* to species until May 17, when the prevalent larval species were summer floodwater *Aedes*. After that time, we returned to genera level identifications. *Culex* larvae are always identified to species to differentiate vectors. Staff process lower priority samples as time permits and those are identified to species. In 2020, lab staff identified 12,832 larval samples (Fig. 1.4). The 25-year average is 20,202 larval samples per year.

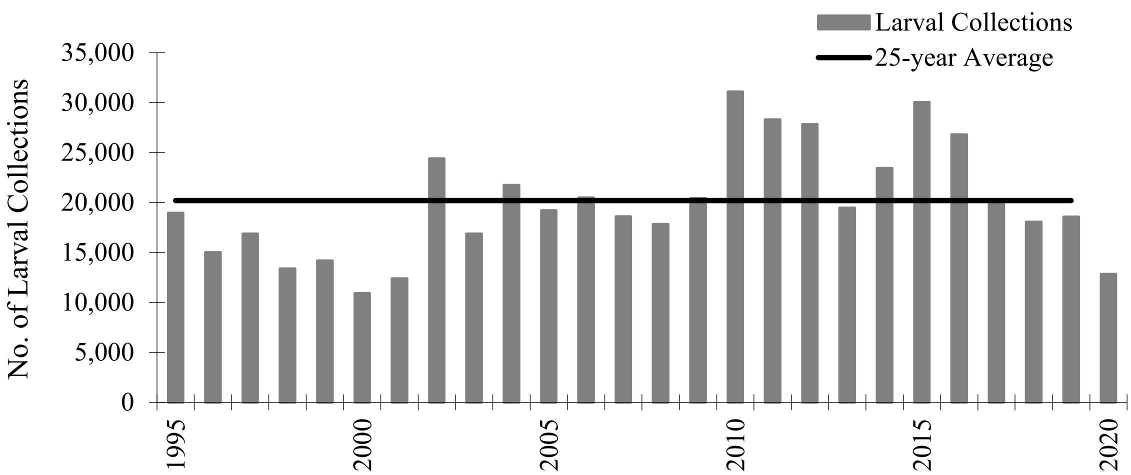


Figure 1.4 Yearly total larval collections, 1995-2020, and 25-year average. Prior to 2015, these totals did not include container samples.

The results of 9,168 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 was the most common species from wetland habitats (18.8% of total) followed by *Ae. cinereus* (17.1%), *Cx. territans* (13.2%), and *Ae. excrucians* (8.8%). In 5th and 6th place were *Cs. inornata* (5.6%) and *Cx. restuans* (5.1%). Again in 2020, species level identifications were done for air site samples to identify spring *Aedes*, which led to increased percentages of occurrence of some spring *Aedes* species from years past (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 stormwater structure samples, 2020; the total number of samples processed to species is in parentheses.

Species	North (2,007)	East (1,357)	South Rosemount (642)	South Jordan (1,650)	West Plymouth (1,220)	West Maple Grove (887)	Wetland Total (7,763)	Structures Total (1,405)
	Percent of samples where species occurred by facility							
Aedes abserratus	4.53	2.95	0.31	0.06	1.56	1.24	2.11	-
aurifer	0.20	-	-	0.06	0.08	-	0.08	-
canadensis	0.85	0.52	3.58	1.88	1.39	0.45	1.28	-
cinereus	25.41	7.44	8.10	14.97	18.28	21.98	17.11	0.07
dorsalis	-	-	-	-	-	-	-	-
euedes	0.05	-	-	-	-	-	0.01	-
excrucians	17.89	7.00	2.80	1.88	4.34	14.43	8.81	-
fitchii	5.68	0.74	0.62	0.18	0.08	1.24	1.84	-
flavescens	-	-	-	-	-	-	-	-
hendersoni	-	-	-	-	-	-	-	0.07
implicatus	0.05	0.15	-	-	0.16	0.11	0.08	-
intrudens	-	-	-	-	-	-	-	-
japonicus	0.35	1.11	0.16	0.24	0.08	-	0.36	19.15
nigromaculis	-	-	-	-	-	-	-	-
provocans	0.25	0.52	-	-	-	-	0.15	-
punctor	1.94	3.24	1.40	0.12	1.39	1.24	1.57	-
riparius	0.85	0.44	0.16	0.06	0.33	1.80	0.58	-
spencerii	-	-	-	-	-	-	-	-
sticticus	0.20	0.52	1.09	0.30	-	-	0.30	-
stimulans	3.99	2.87	2.18	0.91	1.97	5.07	2.80	-
triseriatus	0.10	0.66	0.16	0.06	-	-	0.17	1.21
trivittatus	0.75	3.32	1.71	2.36	0.82	0.11	1.56	0.14
vexans	22.52	23.80	8.10	24.67	12.05	8.68	18.78	4.20
Ae. unidentifiable	57.80	40.31	77.73	50.85	68.20	71.48	58.11	11.81
Anopheles earlei	-	-	-	-	-	-	-	-
punctipennis	0.20	0.37	0.16	-	0.08	-	0.14	0.21
quadrimaculatus	1.25	1.25	0.16	0.18	-	0.11	0.61	0.28
walkeri	0.05	0.07	-	0.06	-	-	0.04	0.21
An. unidentifiable	2.14	3.98	0.62	2.61	1.07	0.90	2.13	0.71
Culex erraticus	-	-	-	-	-	-	-	-
pipiens	1.00	6.63	1.25	1.45	1.31	1.35	2.19	30.53
restuans	3.64	9.65	4.21	4.91	5.49	2.25	5.14	54.80
salinarius	-	-	-	-	-	-	-	0.07
tarsalis	0.20	0.44	0.16	0.36	0.41	0.11	0.30	0.21
territans	10.86	25.94	5.45	14.24	10.66	5.75	13.15	5.41
Cx. unidentifiable	1.05	3.02	2.18	2.30	2.05	1.24	1.93	50.39
Culiseta inornata	2.04	3.54	5.76	10.91	7.21	6.31	5.80	2.06
melanura	0.10	-	-	-	-	-	0.03	-
minnesotae	0.10	0.15	0.16	0.12	0.16	0.56	0.18	-
morsitans	-	-	-	-	-	-	-	-
Cs. unidentifiable	1.20	0.88	1.09	0.97	0.57	1.47	1.02	-
Or. signifera	-	-	-	-	-	-	-	0.07
Ps. ciliata	-	-	-	-	-	-	-	-
ferox	-	0.22	0.16	-	0.16	-	0.08	-
horrida	0.05	0.07	-	0.06	-	-	0.04	-
Ps. unidentifiable	0.05	0.29	1.40	0.30	0.16	-	0.27	-
Ur. sapphirina	2.64	4.35	1.40	2.18	0.90	1.13	2.29	0.07

Adult Mosquito Collections

The District uses a variety of surveillance strategies to collect adult mosquitoes which exploit 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 containing 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 19 weeks, May 18 – September 21.

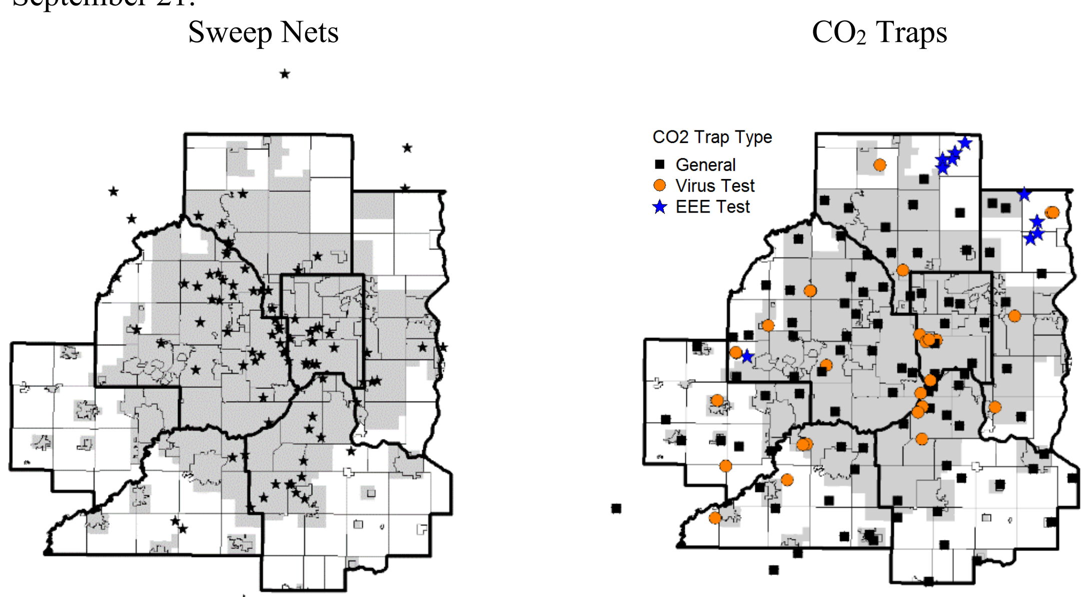


Figure 1.5 Locations of weekly sweep net and CO_2 traps used to monitor general mosquito populations and disease vectors (virus test and EEE test), 2020.

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., *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. There were 87 sweep locations in 2020, and the number of collectors varied from 38-70 per evening. The treatment threshold for sweep net sampling is two mosquitoes per two-minute sweep for *Aedes* and one mosquito per two-minute sweep for *Culex*4 and *Ae. japonicus*.

Staff made 1,087 collections containing 1,192 mosquitoes in 2020. The average number of summer *Aedes* collected in the evening sweep net collections in 2020 was similar to 2019 (Table 1.2). Many more *Cq. perturbans* were detected – the most since 2017. Spring *Aedes* and *Cx. tarsalis* were at very low levels. The summer *Aedes*, spring *Aedes*, and *Cx. tarsalis* were below the 20-year average. *Coquillettidia perturbans* averages were higher than the 20-year average.

Table 1.2 Average number of mosquitoes collected per evening sweep net collection within the District, 2016-2020 and 20-year average, 2000-2019 (± 1 SE).

Year	Summer *Aedes*	*Cq. perturbans*	Spring *Aedes*	*Cx. tarsalis*
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
2019	0.55	0.14	0.09	0.003
2020	0.53	0.48	0.02	0.001
20-yr Avg.	1.70 (±0.30)	0.32 (±0.05)	0.11 (±0.03)	0.008 (±0.001)

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 five 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 2020, we placed 139 traps at 127 locations (twelve of these locations have low traps paired with elevated traps) to allow maximum coverage of the District (Figure 1.5). An additional three traps were 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*4 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 2,217 District low CO_2 trap collections taken contained 706,963 mosquitoes in 2020. The total number of these traps operated weekly varied from 112-119. The average number of mosquitoes detected in CO_2 traps is found in Table 1.3. As is typical, summer *Aedes* (predominantly *Ae. vexans*) were the most abundant species in the District. Population levels were higher than last year, but still below the 20-year average. Twice as many *Cq. perturbans* were collected in 2020 than in 2019. Captures of spring *Aedes* decreased to half of the long-term average. *Culex tarsalis* numbers were the lowest in the past five years. This was the fifth consecutive year that *Cx. tarsalis* numbers were well below the District's 20-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, 2016-2020 and 20-year average, 2000-2019 (± 1 SE).

Year	Summer *Aedes*	*Cq. perturbans*	Spring *Aedes*	*Cx. tarsalis*
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
2019	160.1	66.1	6.5	0.7
2020	182.4	127.3	3.5	0.2
20-yr Avg.	203.9 (±27.5)	53.5 (±7.3)	7.8 (±1.8)	1.8 (±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. Priority area 1 (P1) receives full larval control. A full description of priority areas is in Chapter 4: Mosquito Control.

Spring *Aedes* populations were first detected May 26 and they were mostly confined to a few locations on the outer edges of the District (Figure 1.6). A large, localized population was detected on June 1 in northeastern Anoka County. Typically, higher levels of spring *Aedes* are found in Anoka and Washington counties.

The first detections of the summer *Aedes* occurred May 26 in northwestern Anoka County (Fig. 1.7). Very high levels were widespread from June 1 – June 8. Beginning June 15, localized populations occurred in southern areas of the District. July 13 – 27 showed decreasing populations, and intense localized populations were detected through August. Summer *Aedes* were detected at low levels through September.

Coquillettidia perturbans was first detected in higher levels June 1 (Figure 1.8). Peak emergence occurred the first week of July and declined thereafter. The highest levels occurred outside of P1 on the outer borders of the District.

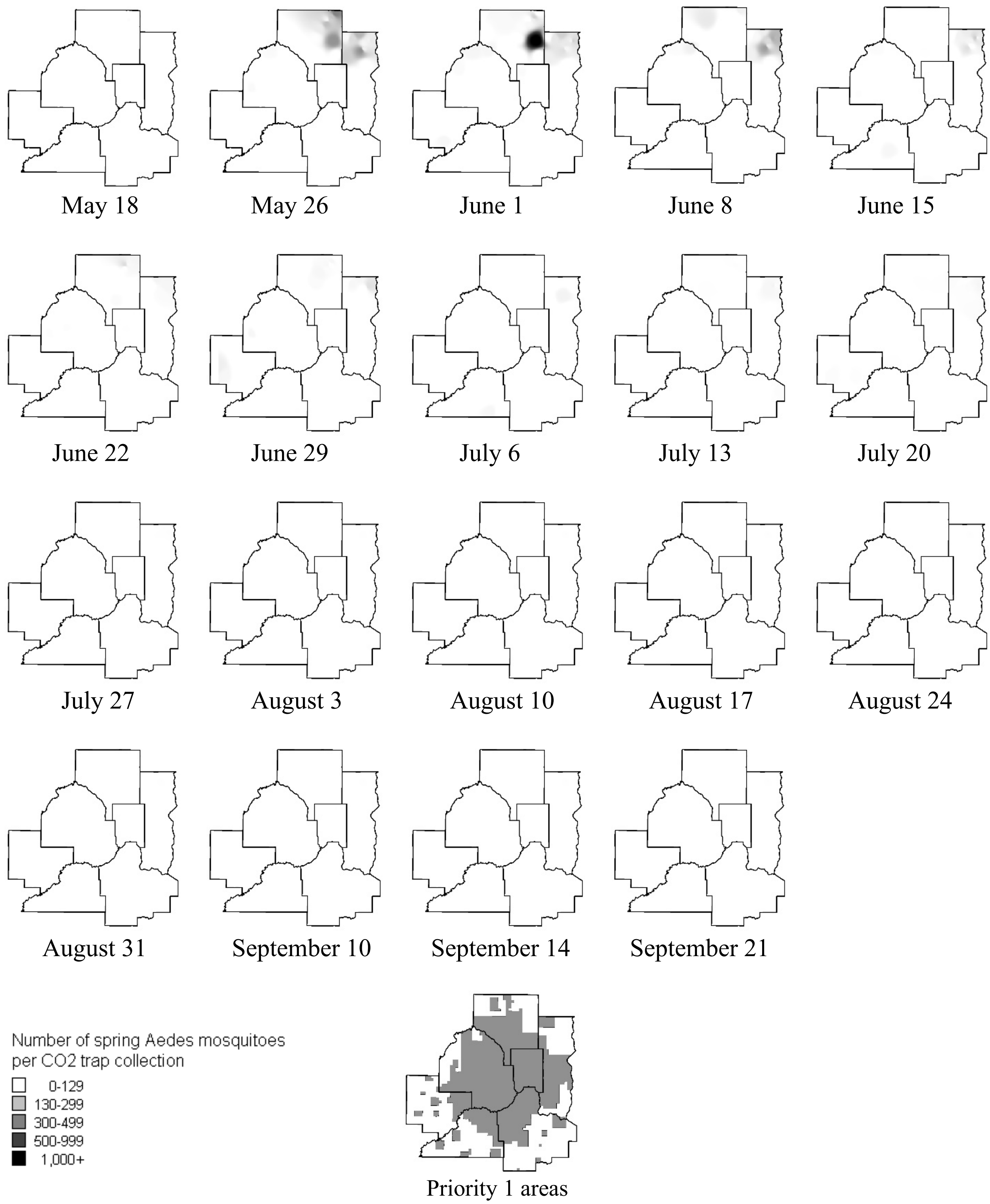


Figure 1.6 Number of spring *Aedes* in District low (5 ft) CO_2 trap collections, 2020. The number of traps operated per night varied from 112-119. Inverse distance weighting was the algorithm used for shading of maps. Treatment threshold is >130 mosquitoes/trap night. Priority 1 area map for reference.

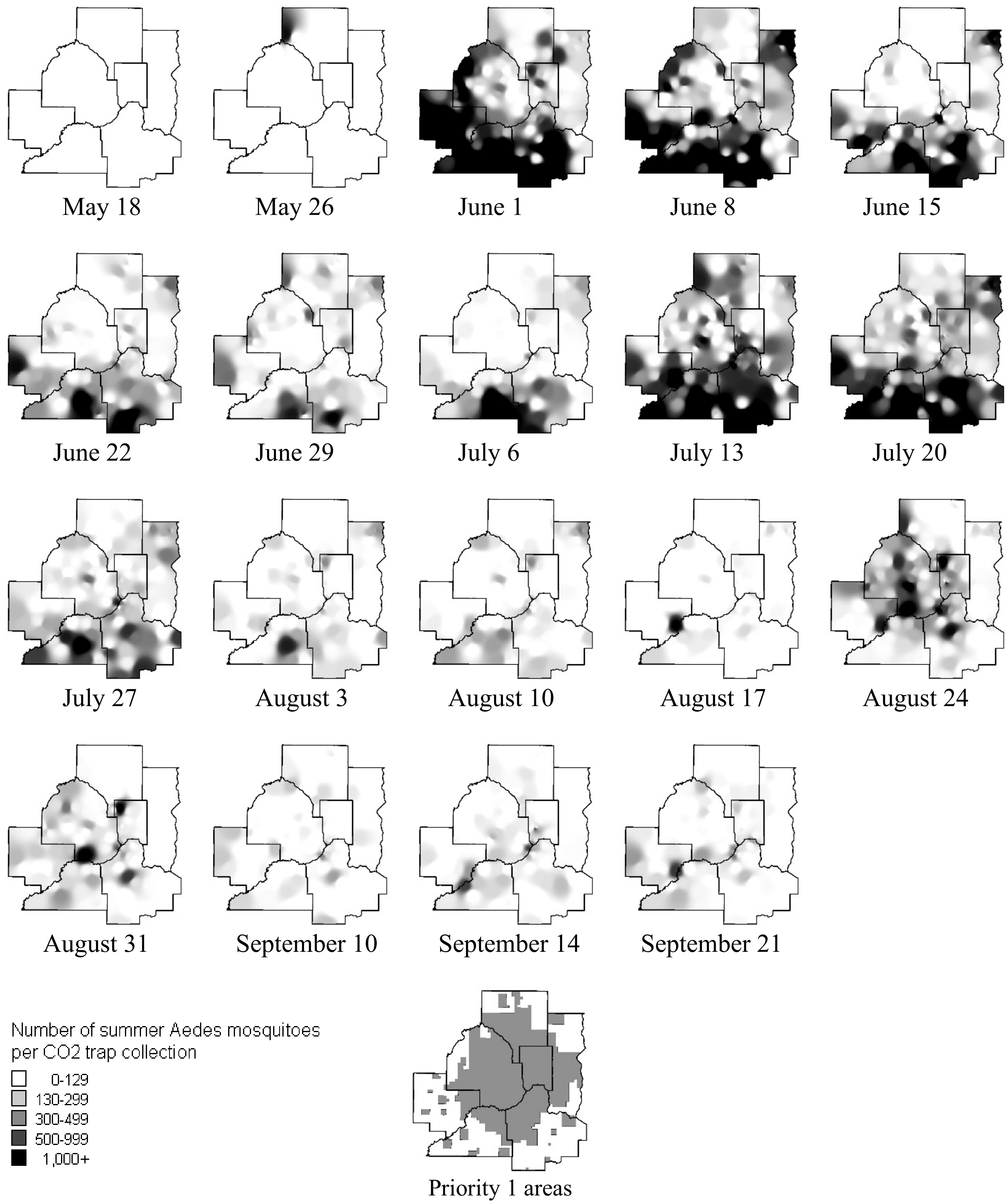


Figure 1.7 Number of summer *Aedes* in District low (5 ft) CO_2 trap collections, 2020. The number of traps operated per night varied from 112-119. Inverse distance weighting was the algorithm used for shading of maps. Treatment threshold is >130 mosquitoes/trap night. Priority 1 area map for reference.

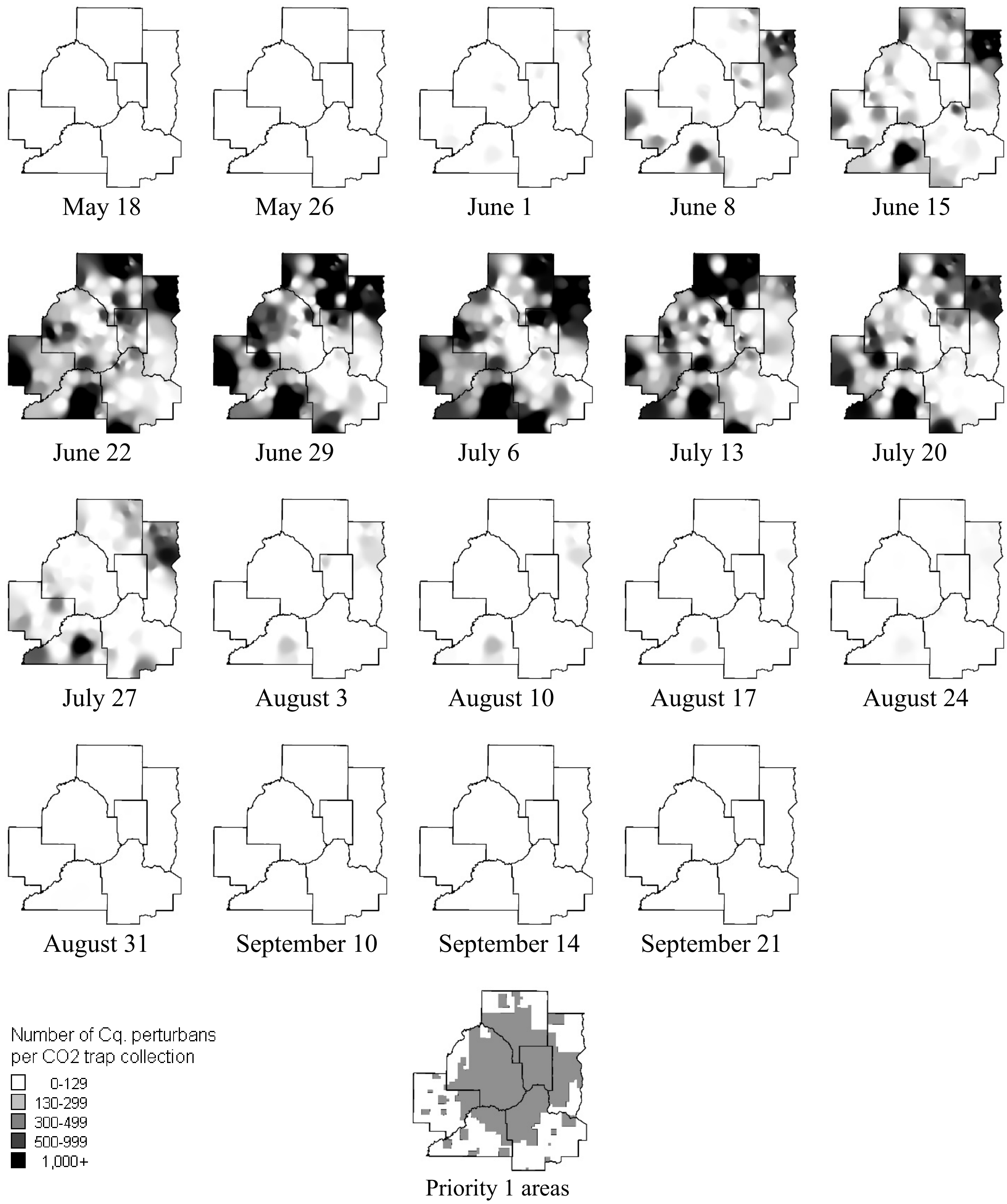


Figure 1.8 Number of *Cq. perturbans* in District low (5 ft) CO_2 trap collections, 2020. The number of traps operated per night varied from 112-119. Inverse distance weighting was the algorithm used for shading of maps. Treatment threshold is >130 mosquitoes/trap night. Priority 1 area map for reference.

Seasonal Distribution As described earlier, spring *Aedes*, summer *Aedes,* and *Cq. perturbans* have different patterns of occurrence during the season based on their phenology. 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 9:00 p.m. on the scheduled sampling night. In 2020, sampling with CO_2 traps and sweep nets started May 18. Except for September 9, temperatures at the time of sampling were well above the minimum mosquito flight threshold.

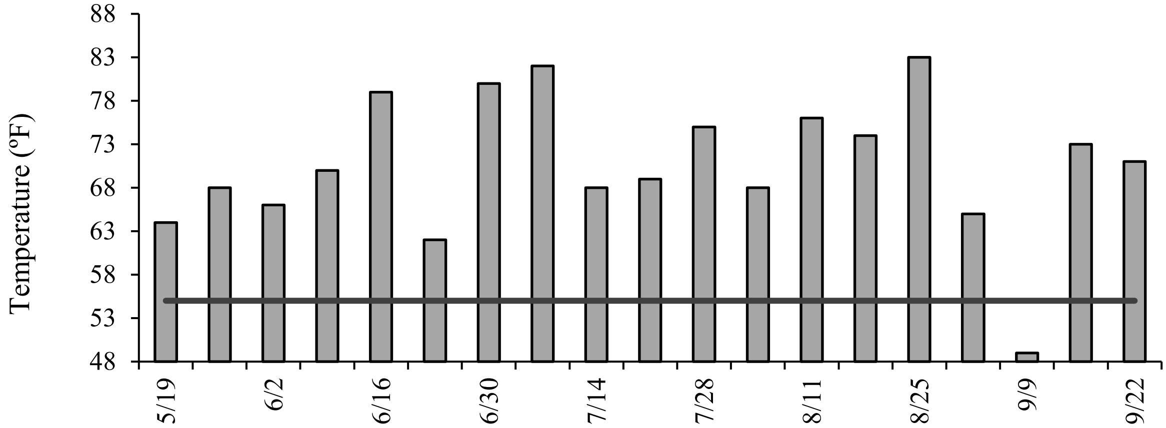


Figure 1.9 Temperature at 9:00 p.m. on actual dates of Monday night surveillance, 2020 (source: National Weather Service, Twin Cities Station). The black horizonal line indicates the mosquito flight threshold, 55°F.

Figures 1.10 and 1.11 show the seasonal distribution of the three major groups of mosquitoes detected by sweep netting and CO_2 traps during the mosquito season. Adult spring *Aedes* were first detected May 26 in sweep samples and on May 19 in CO_2 samples. Highest levels in sweep nets were detected on May 26 and declined thereafter (Fig. 1.10). Populations peaked early and were well below the 20-year average. Highest captures in CO_2 traps occurred on May 27 and June 1. Populations declined through July 13 and very low numbers were detected through August 31 (Fig. 1.11). For most of the season, spring *Aedes* were below the 20-year average.

Summer *Aedes* were first detected in sweep net samples on May 27 and in CO_2 traps on May 18 (Fig. 1.10 and Fig. 1.11, respectively). High levels in sweeps occurred twice – on June 8 and July 13 (Fig. 1.10). Populations declined thereafter and remained low throughout the summer. The summer *Aedes* in sweep samples were well below the 20-year average. CO_2 trapping detected summer *Aedes* the first sampling night and the highest levels were seen on June 2 (Fig 1.11). Another peak occurred on July 14 with levels declining until a late, smaller emergence was detected on August 25. Mosquito levels in CO_2 traps peaked above the 20-year average twice during the summer.

The single generation *Cq. perturbans* was initially detected June 8 for sweep nets and May 27 for CO_2 traps. Sweep nets detected the peak on July 13 and the last *Cq. perturbans* was collected on August 17 (Fig. 1.10); *Cq. perturbans* were collected in numbers well above the 20-year average from June to July 20 (Fig. 1.10). Highest levels in CO_2 traps occurred June 30, earlier than normal and were well above the 20-year average (Fig. 1.11). Populations fell throughout July and were collected every collection day to September 22.

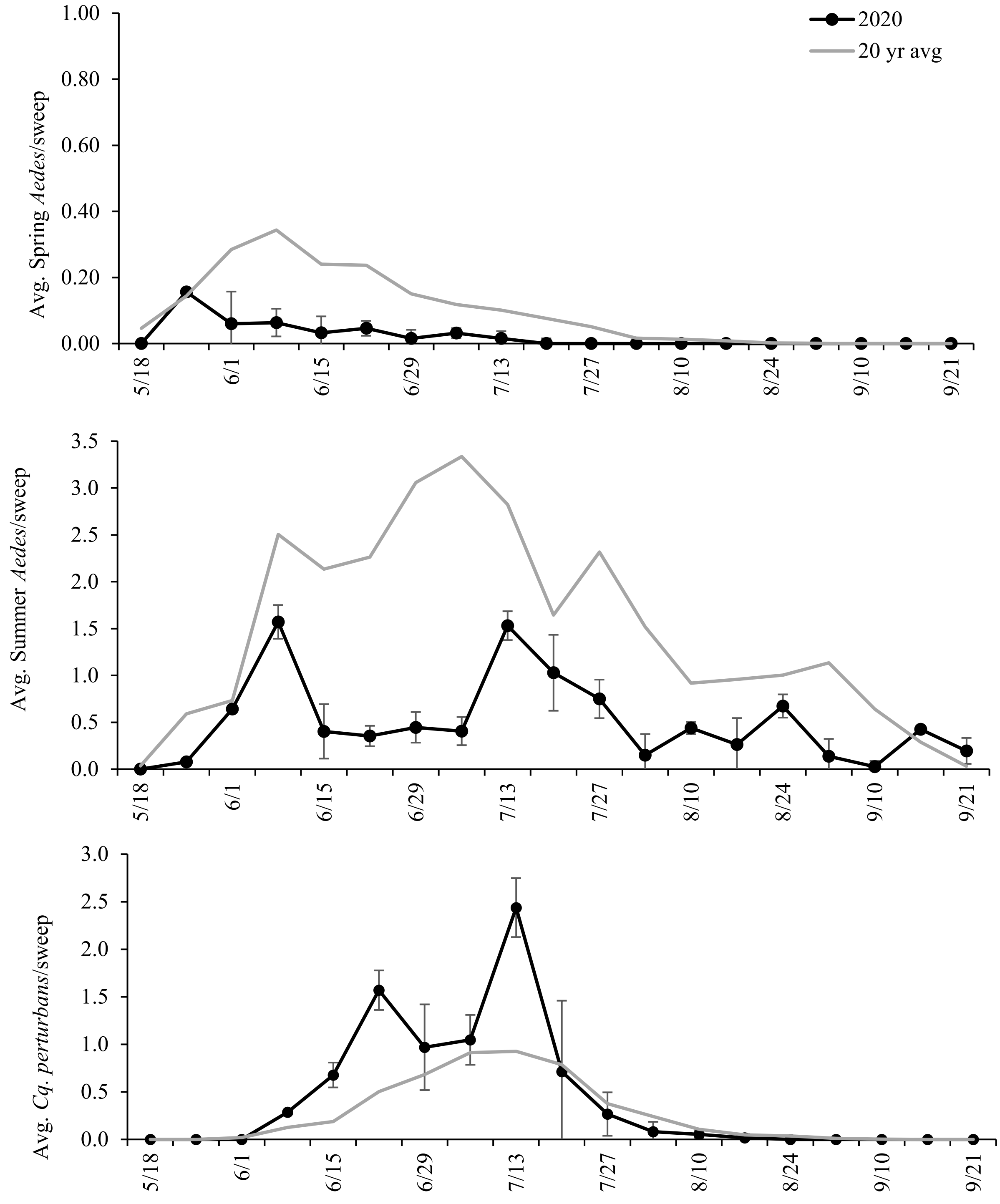


Figure 1.10 Average number of spring *Aedes*, summer *Aedes*, and *Cq. perturbans* per sweep net collection, 2020 vs. 20-year average. Dates are the Mondays of each week. Error bars equal + 1 standard error of the mean.

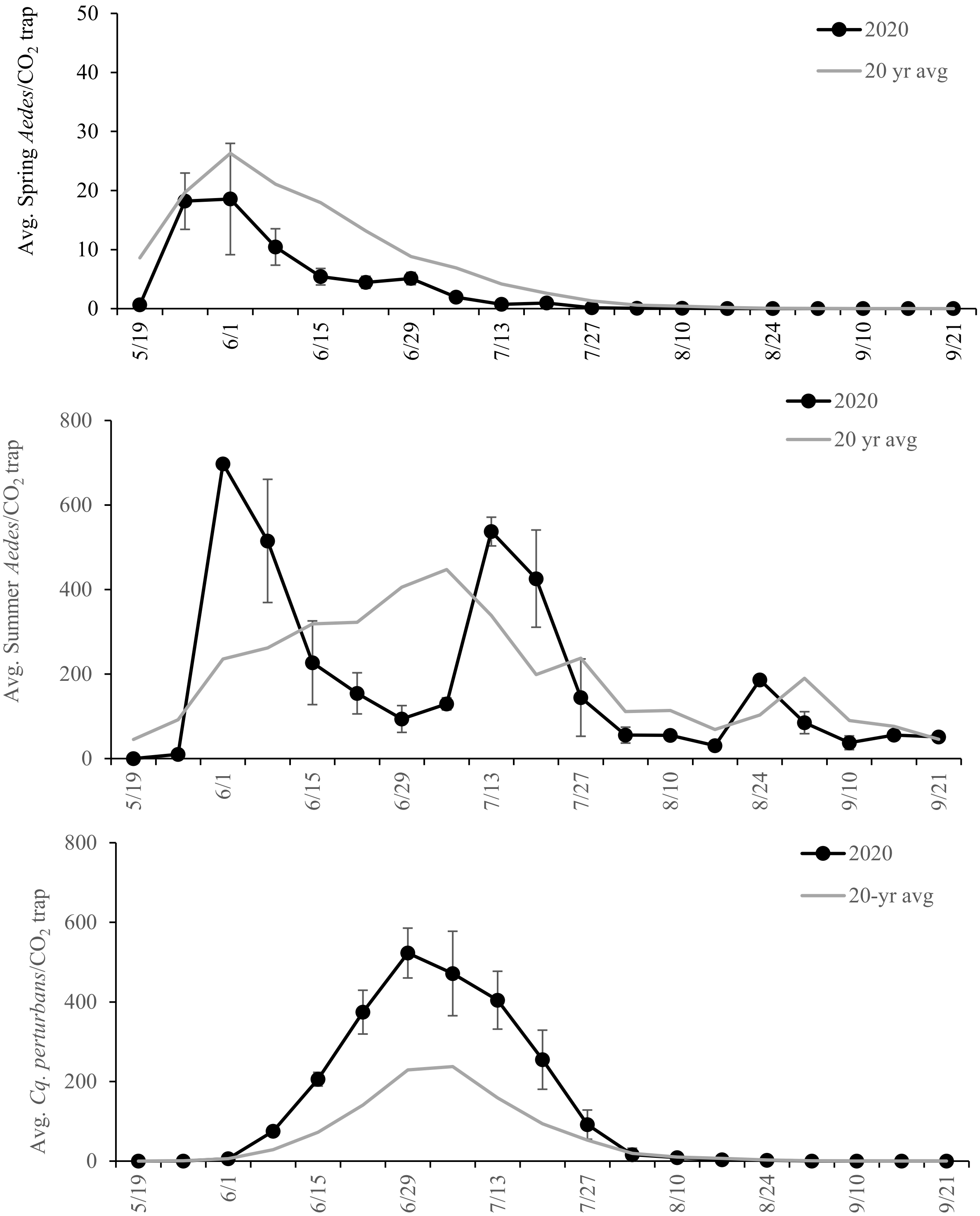


Figure 1.11 Average number of spring *Aedes*, summer *Aedes*, and *Cq. perturbans* per CO_2 trap, 2020 vs. 20-year average. Dates are the Mondays of each week. Error bars equal ± 1 standard error of the mean.

The difference in mosquito levels in priority zones (P1 = full larval treatment and P2 = no larval treatment) is shown in Figure 1.12. Spring *Aedes* levels were low in both P1 and P2, Summer *Aedes* were high in both zones, but much higher in zone 2. *Coquillettidia perturbans* levels were also much higher in P2.

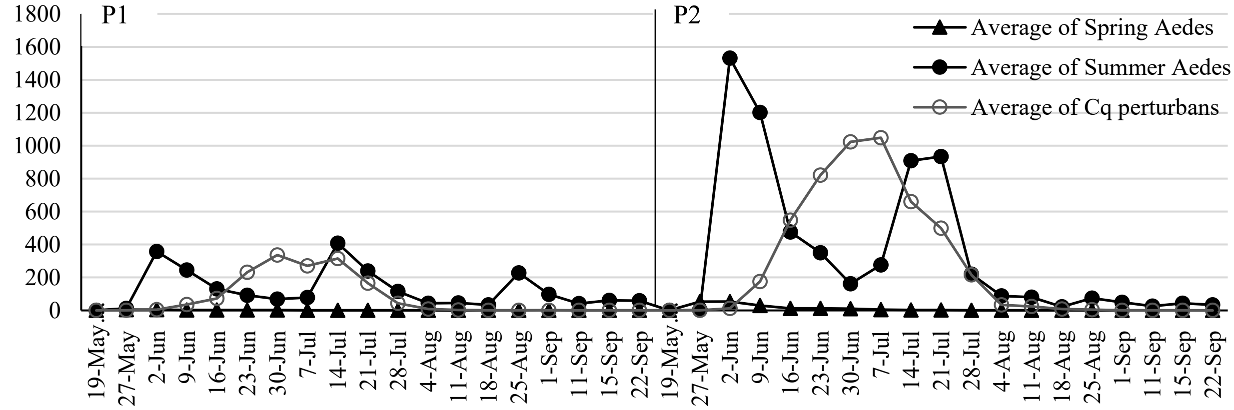


Figure 1.12 Average number of spring *Aedes*, summer *Aedes*, and *Cq*. *perturbans* per CO_2 trap, 2020 in P1 and P2.

New Jersey (NJ) Light 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. The 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 1.13). Traps 9 and 16 have operated from 1965-2020. The CA1 trap started in 1991. Trap 13 has been at MMCD's Jordan Office location since 1998.

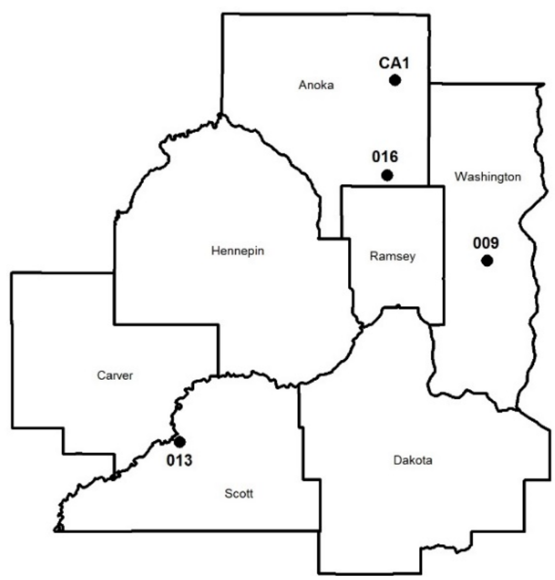


Figure 1.13 NJ light trap locations, 2020.

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

The top five most abundant species collected were *Cq. perturbans* (64.1% of all female mosquitoes captured), *Ae. vexans* (21.8%), *Ae. absserratus/punctor* (7.2% - includes *Ae. abserratus*, *Ae. punctor*, and unidentifiable *abserratus/punctor*), *An. quadrimaculatus* (2.3%), and *Ae. cinereus* (0.86%) (Table 1.4). The Carlos Avery trap (CA1) collected 85.4% of all females collected followed by Lino Lakes (7.4%, Trap 16), Jordan (3.8%, Trap 13), and Lake Elmo (3.4%, Trap 9).

Trap 9, located in Lake Elmo, 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*.

Trap 13 is located in Jordan, 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* and *Cq. perturbans*. Third most abundant species was *An. quadrimaculatus*.

Trap 16 is located in Lino Lakes, Anoka County. The most abundant species collected in this trap was *Ae. vexans* followed by *Cq. perturbans*.

CA1, located in the northern part of the District in Columbus, Anoka County, 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 top five species were captured most frequently in CA1. Ninety-five percent of all *Cq. perturbans,* 59.2% of *Ae.* vexans, 99.7% of the spring *Aedes* species of *Ae. abserratus* and *Ae. punctor*, and 95.2% of *Ae. cinereus* were collected in this location. Of the *Anopheles* species, 79% of the *An. punctipennis*, 66% of *An. quadrimaculatus*, and 97.7% of *An. walkeri* were collected in CA1.

Table 1.4 Total numbers and frequency of occurrence for each species collected in New Jersey light traps, May 8 - September 25, 2020.

	Trap Code, Location, and Number of Collections				Summary Statistics		
	9	13	16	CA1			
	Lake	Jordan	Lino	Carlos	Total		
	Elmo	Office	Lakes	Avery	Collected	% Female	Avg per
Species	134	135	140	137	546	Total	Night
Ae. abserratus	1	0	0	518	519	1.07%	0.95
atropalpus	0	0	0	0	0	0.00%	0.00
aurifer	0	0	0	0	0	0.00%	0.00
canadensis	0	0	0	1	1	0.00%	0.00
cinereus	2	9	9	397	417	0.86%	0.76
diantaeus	0	0	0	1	1	0.00%	0.00
dorsalis	0	0	0	0	0	0.00%	0.00
excrucians	0	0	0	33	33	0.07%	0.06
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	4	0	2	3	9	0.02%	0.02
nigromaculus	0	0	0	0	0	0.00%	0.00
punctor	0	0	1	209	210	0.43%	0.38
riparius	0	0	0	0	0	0.00%	0.00
spencerii	0	0	0	0	0	0.00%	0.00
sticticus	17	31	2	0	50	0.10%	0.09
stimulans	0	0	0	0	0	0.00%	0.00
provocans	0	0	0	1	1	0.00%	0.00
triseriatus	0	0	0	17	17	0.04%	0.03
trivittatus	62	21	3	15	101	0.21%	0.18
vexans	736	1,005	2,563	6,264	10,568	21.78%	19.36
abserratus/punctor	1	0	9	2,764	2,774	5.72%	5.08
Aedes unidentifiable	64	5	5	48	122	0.25%	0.22
Spring *Aedes* unident.	0	0	24	44	68	0.14%	0.12
Summer *Aedes* unident.	16	0	2	1	19	0.04%	0.03
An. barberi	0	0	0	0	0	0.00%	0.00
earlei	0	0	0	0	0	0.00%	0.00
punctipennis	7	8	0	59	74	0.15%	0.14
quadrimaculatus	310	58	10	745	1,123	2.31%	2.06
walkeri	7	1	8	693	709	1.46%	1.30
An. unidentifiable	22	2	0	224	248	0.51%	0.45
Cx. erraticus	0	0	0	0	0	0.00%	0.00
pipiens	0	1	3	7	11	0.02%	0.02
restuans	7	2	13	36	58	0.12%	0.11
salinarius	0	0	0	0	0	0.00%	0.00
tarsalis	1	2	0	7	10	0.02%	0.02
territans	1	0	6	3	10	0.02%	0.02
Cx. unidentifiable	2	0	2	1	5	0.01%	0.01
Cx. pipiens/restuans	12	5	10	47	74	0.15%	0.14
Cs. inornata	5	6	4	72	87	0.18%	0.16
melanura	0	0	0	1	1	0.00%	0.00
minnesotae	0	1	1	7	9	0.02%	0.02
morsitans	0	0	0	4	4	0.01%	0.01
Cs. unidentifiable	0	0	0	2	2	0.00%	0.00
Cq. perturbans	247	547	793	29,511	31,098	64.10%	56.96
Or. signifera	0	0	0	0	0	0.00%	0.00
Ps. ferox	0	0	0	0	0	0.00%	0.00
horrida	0	0	0	0	0	0.00%	0.00
Ps. unidentifiable	0	0	0	0	0	0.00%	0.00
Ur. sapphirina	13	11	17	31	72	0.15%	0.13
Unidentifiable	1	6	0	4	11	0.02%	0.02
Female Total	1,538	1,721	3,487	41,770	48,516	100.00%	88.86
Male Total	339	358	597	5,084	6,378		
Grand Total	1,877	2,079	4,084	46,854	54,894		

Coquillettidia perturbans **Population Prediction**

Coquillettidia perturbans is typically a common species with 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, typically peaking around Independence Day. Adult populations are influenced by rainfall amounts from the previous year. Higher *Cq. perturbans* captures in CO_2 traps occurred (2003, 2011, and 2017) following years with above normal rainfall amounts (Figure 1.14). Analyses started 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 2020 was 90.2 *Cq. perturbans* per CO_2 trap, but the actual rate was 127.3 (Figure 1.14). The predicted number of *Cq. perturbans* collected per CO_2 trap in 2021 is 47.3. This model explains ~79% of the variation in predicted *Cq. perturbans* abundance (adjusted R-squared = 0.794). The prediction helps identify population trends for the coming year, and larval dips confirm abundance and treatment locations.

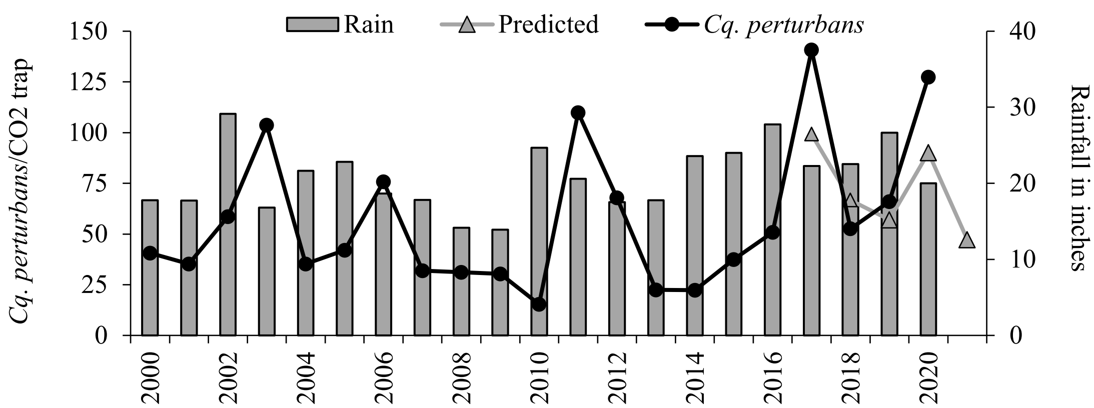


Figure 1.14 Average number of *Coquillettidia perturbans* in CO_2 traps and average seasonal rainfall per gauge, 2000-2020. The gray line shows the predicted amounts for 2017 and beyond.

Rare Detections

With our Monday Night Network, we monitor other species which are considered uncommon or rare in Minnesota. *Culex erraticus*, *Anopheles earlei*, *An. quadrimaculatus*, and *Psorophora* species have experienced significant changes in populations in recent years.

Culex erraticus larvae were detected in 1961 (one sample from Washington County) and again in 2012 (six sites in Washington and Scott counties). The first adult specimens weren't collected until 1988 when four were detected in NJ light trap samples. Since then, we have been detecting *Cx. erraticus* sporadically. Numbers have remained relatively low, but in 2012, 650 adults were collected. From 2013 to 2019 the total collected have ranged between 2-21; only two were detected in 2019 and 33 in 2020.

Anopheles quadrimaculatus is no longer considered rare in the District. A marked increase in numbers was first detected in 2006 and populations have been detected in higher levels since then (Fig. 1.15). The average collected per year from 2002-2009 is 104.87 and the average collected per year from 2010-2020 is 1,742.

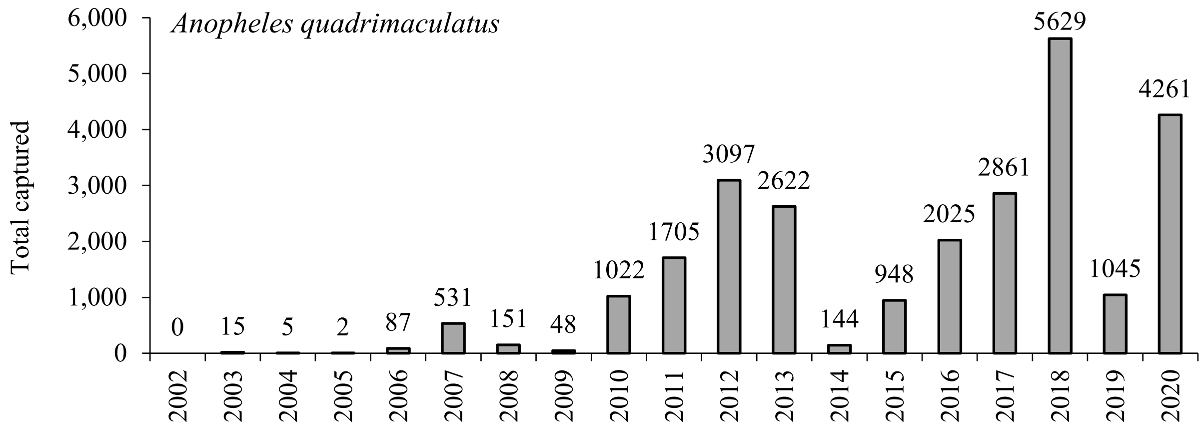


Figure 1.15 Total yearly *An. quadrimaculatus* collected from Monday Night CO_2 traps (low, high, and any outside District), 2002-2020.

Psorophora ferox and *Ps. horrida* numbers have also been increasing (Fig. 1.16). Specimens that are missing the taxonomic characters needed for identification to species are recorded as *Psorophora* species but are likely either *Ps. ferox* or *Ps. horrida*. From 2005-2009, 205 *Psorophora* spp. specimens were collected and from 2010-2020, 6,912 were collected. The average collected per year was 41 during 2005-2009 and increased over 1,400% during 2010-2020 to 628.3 per year. In 2020, we detected one specimen of *Ps. ciliata*, a rare southern species that is found in the District periodically.

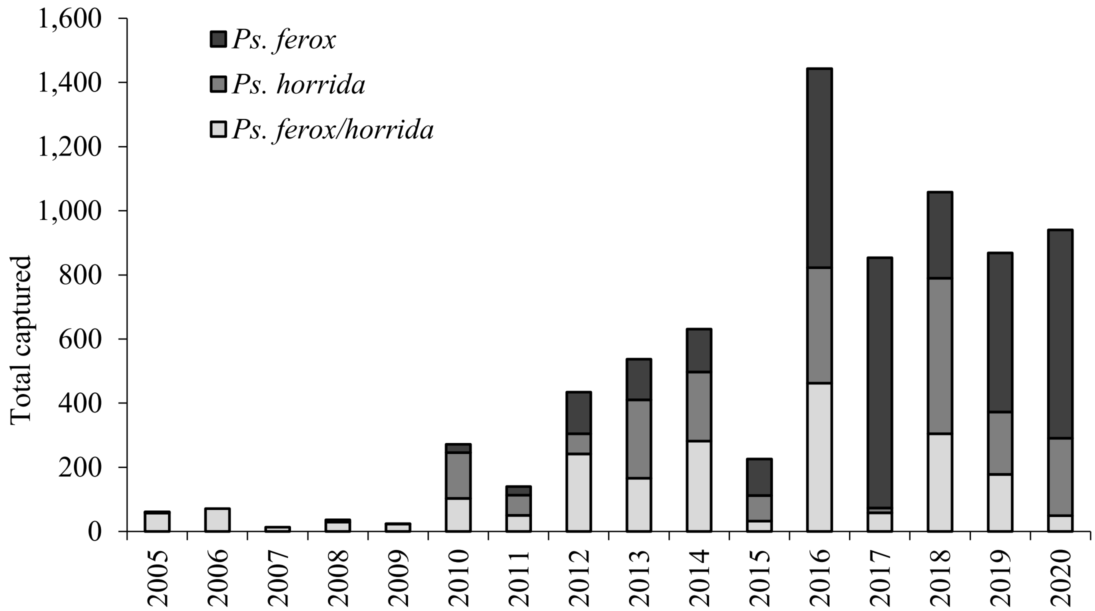


Figure 1.16 Total yearly *Ps. ferox, Ps. horrida,* and *Ps. ferox/horrida* collected from Monday Night CO_2 traps (low, high, and any outside District), 2005-2020.

2021 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. In addition, we will designate a subset of CO_2 trap locations for full species identifications or re-instate NJ traps at sites previously sampled. Additionally, we plan to convert archived surveillance data, which are currently in legacy formats, to the new cloud database.

Chapter 2 Mosquito-borne Disease

2020 Highlights

- There were no mosquito-borne disease cases reported in Minnesota residents
- Eastern equine encephalitis was diagnosed in two Minnesota horses
- West Nile virus detected in six District mosquito samples
- Collected and recycled 11,824 tires

2021 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 *Aedes albopictus* and other exotic species
- Continue *Culiseta 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 virus (WNV).

La Crosse encephalitis prevention services were initiated in 1987 to identify areas within the District where significant risk of acquiring LAC 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. *Culex tarsalis* 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.

2020 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 2020, District staff recycled 11,824 tires that were collected from the field (Table 2.1). Since 1988, the District has recycled 700,377 tires. In addition, MMCD eliminated 3,134 containers and filled 375 tree holes (Table 2.1). This reduction of larval habitats occurred through inspecting public and private properties, and while conducting a variety of mosquito, tick, and black fly surveillance and control activities.

Table 2.1 Number of tires, containers, and tree hole habitats eliminated during each of the past 12 seasons.

Year	Tires	Containers	Tree holes	Total
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
2019	9,763	1,611	395	11,769
2020	11,824	3,134	375	15,333

*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 2020, there were 72 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 2020, MMCD staff collected 2,001 aspirator samples to monitor *Ae. triseriatus* populations. Inspections of wooded areas and surrounding residential properties to eliminate larval habitat were provided as a 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 235 aspirator samples. Adulticides were applied to wooded areas in 64 of those cases. Adult *Ae. triseriatus* were captured in 437 of 1,604 wooded areas sampled. The mean *Ae. triseriatus* capture was the lowest observed since 2009 (Table 2.2).

Table 2.2 *Aedes triseriatus* aspirator surveillance data – past 20 seasons.

Year	Total areas surveyed	No. with *Ae. triseriatus*	Percent with *Ae. triseriatus*	Total samples collected	Mean *Ae. triseriatus* per sample
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
2019	1,055	342	32.4	1,170	0.97
2020	1,604	437	27.2	2,001	0.57

Aspirator sampling began during the week of June 1 and continued through the week of September 28. Weekly mean collections of *Ae. triseriatus* remained well below the long-term average until the third week of August. Collections from that point on were near or above average (Fig. 2.1). We observed the season peak of 1.0 *Ae. triseriatus* per sample during the week of June 22.

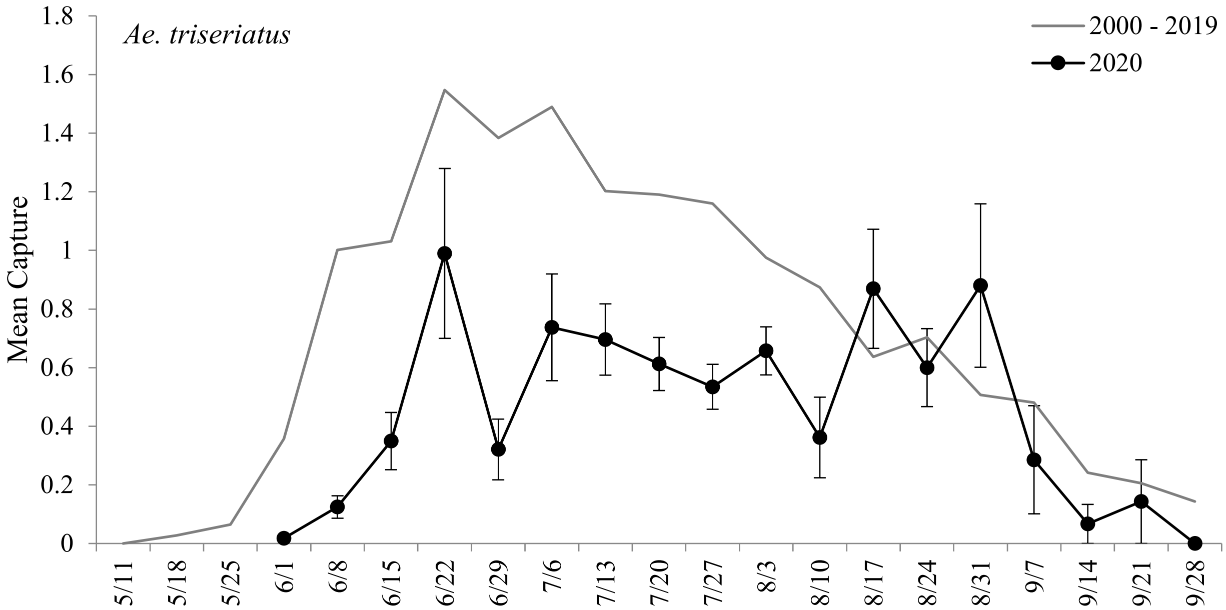


Figure 2.1 Mean number of *Ae. triseriatus* adults in 2020 aspirator samples plotted by week compared to mean captures for the corresponding weeks of 2000-2019. Dates listed are Monday of each week. Error bars equal ± 1 standard error of the mean.

La Crosse Encephalitis in Minnesota There were no LAC cases reported in Minnesota in 2020. Since 1970, the District has had an average of 2.0 LAC cases per year (range 0-10, median 2). Since 1990, the mean is 1.3 cases per year (range 0-8, median 0).

Exotic, Introduced 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 widespread across eastern North American and commonly collected throughout the District.

Aedes albopictus *Aedes albopictus* were collected in 27 samples in 2020. All of the samples were collected from a tire recycling facility or adjacent properties in Scott County.

Specimens were reared from five ovitrap samples collected from July 20 to October 1. Nine gravid trap samples contained *Ae. albopictus*; specimens were collected from June 17 to September 23. Thirteen BG Sentinel samples contained the species with collections occurring from July 8 to September 23. A total of 75 specimens were collected in the 22 samples that contained adult *Ae. albopictus*. The high capture in a gravid trap was ten on September 23 and the high capture in a BG Sentinel trap was five on August 26.

Routine surveillance of tires and containers in and near the area where *Ae. albopictus* were collected by other methods did not result in the collection of *Ae. albopictus* larvae in 2020.

This was the 18th year and ninth consecutive year when *Ae. albopictus* were collected by MMCD staff, the first was in 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 now 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. In 2020 *Ae. japonicus* were more prevalent than in previous seasons.

Aedes japonicus larvae were found in 778 samples. Most were from containers (353), catch basins (210), and tires (155). Larvae were found in other habitats as well, including stormwater structures/artificial ponds (30), wetlands (29), and tree holes (1).

The frequency of *Ae. japonicus* occurrence in larval samples from containers and tires generally increased each year as they spread throughout the District. Following two seasons of decline, the collection frequency rebounded to historical highs in 2020 (Fig. 2.2). *Aedes japonicus* have been collected less frequently from tree holes than in tires and containers. Of eight larval samples from tree holes, only one contained the species in 2020.

Aedes japonicus adults were identified in 904 samples. They were found in 547 aspirator samples, 170 gravid trap samples, 131 CO_2 trap samples, 34 two-minute sweep samples, 15 BG Sentinel trap samples and seven New Jersey trap samples. *Aedes japonicus* were also hatched from 40 of the 70 ovitrap samples that contained mosquito eggs when collected in 2020. There were 112 ovitraps placed in 2020.

In 2020, the rate of capture of *Ae. japonicus* in aspirator samples remained near average until early July, when collections rose above averages of previous seasons. (Fig. 2.3). For comparison, the 2011 to 2019 average represents the period when *Ae. japonicus* has occupied parts of all seven District counties. the 2014 – 2019 average represents the period when the species has been found consistently throughout all areas of the District. The peak rate of capture in 2020 occurred during the week of August 31 at 3.1 *Ae. japonicus* per sample.

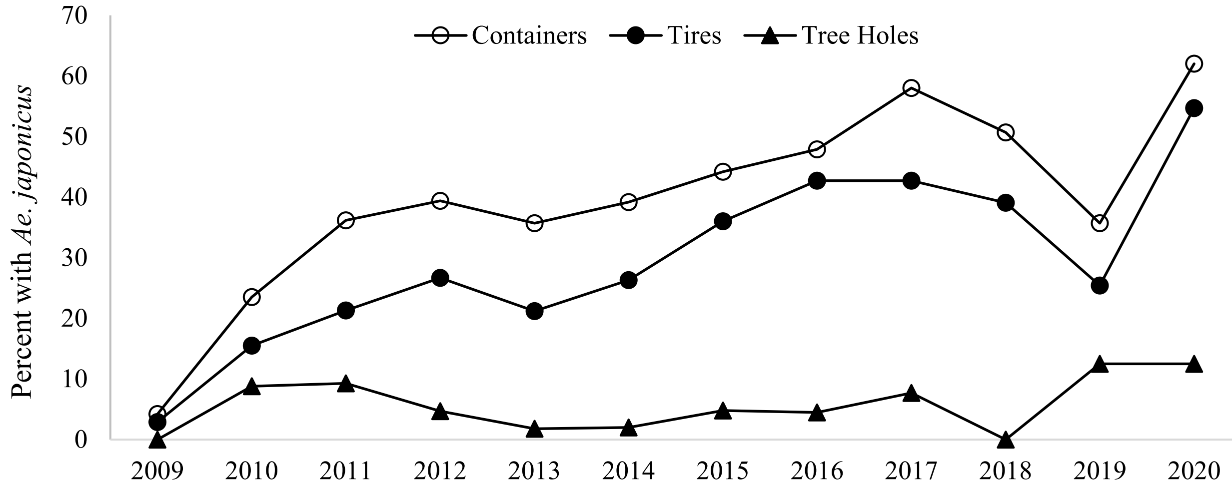


Figure 2.2 Percentage of larval samples from containers, tires, and tree holes containing *Ae. japonicus* by year.

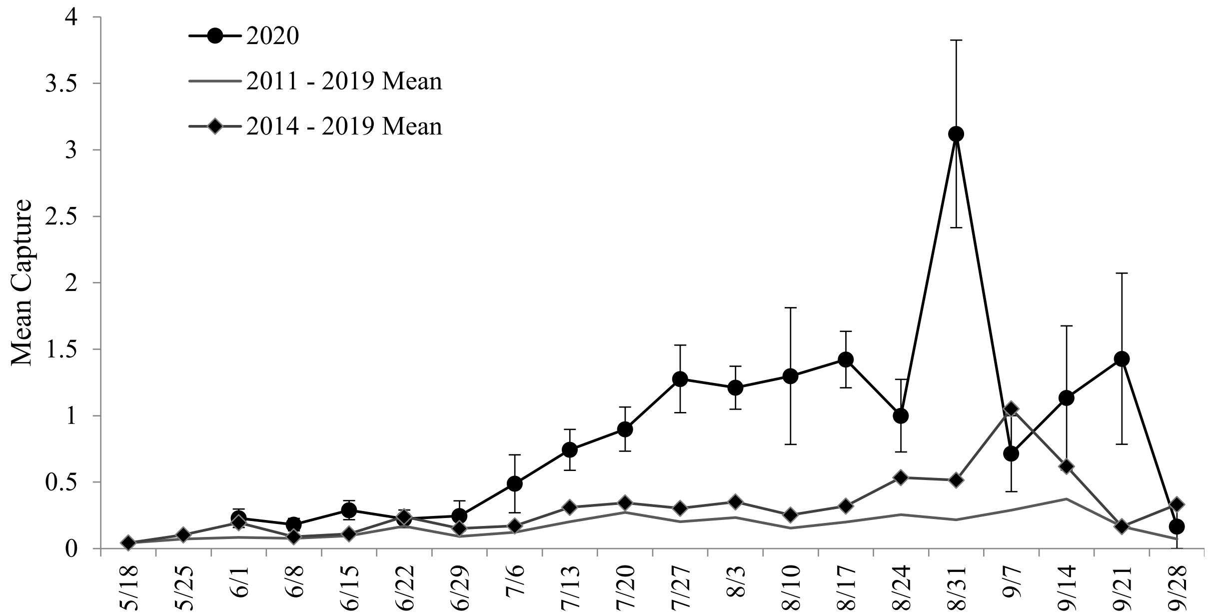


Figure 2.3 Mean number of *Ae. japonicus* adults in 2020 aspirator samples plotted by week compared to mean captures for the corresponding weeks of 2011-2019 and 2014-2019. Dates listed are Monday of each week. Error bars equal ± 1 standard error of the mean.

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 City in 1999 and has since spread throughout 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 was detected in 45 states in 2020. The U.S. Centers for Disease Control and Prevention received reports of 540 West Nile illnesses from 40 states. There were 33 fatalities attributed to WNV infections. California reported the greatest number of cases with 184. Nationwide screening of blood donors detected WNV in 127 individuals from 15 states.

WNV in Minnesota For the first time since its arrival here, there were no WNV illnesses reported in residents of Minnesota in 2020. Additionally, there were no reports of WNV illness in horses or other domestic animals in 2020.

WNV in the District There were no WNV illnesses reported in residents of the District in 2020. Since WNV arrived in Minnesota, the District has experienced an average of 9.3 WNV illnesses each year (range 0-25, median 8). When cases with suspected exposure locations outside of the District are excluded, the mean is 7.4 cases per year (range 0-18, median 6).

Surveillance for WNV - Mosquitoes Surveillance for WNV in mosquitoes began during the week of June 1 and continued through the week of September 21. Several mosquito species from 44 CO_2 traps (12 elevated into the tree canopy) and 37 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 546 mosquito pools using the rapid analyte measurement platform (RAMP®), six 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, 2020. 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. erraticus	5	1	0	0.00
Cx. pipiens	1,003	33	1	1.00
Cx. restuans	538	20	0	0.00
Cx. tarsalis	324	49	0	0.00
Cx. pipiens/Cx. restuans	5,464	221	2	0.37
Culex species	5,487	222	3	0.55
Total	12,821	546	6	0.47

The first two WNV positive samples of 2020 were collected on August 12 – a pool of 30 *Cx. pipiens/restuans* collected in Minneapolis and a pool of 50 *Cx. pipiens/restuans* collected in Coon Rapids. This was the third latest date for a season's first detection of WNV in mosquitoes in the District. Two of the WNV positive samples were collected in Anoka County, two in Hennepin County, and one each from Ramsey and Washington counties. All six of the 2020 WNV positive samples were collected by gravid traps.

The WNV cycle was slow to begin in 2020. This was the fifth time since WNV arrived in Minnesota that the first detection of the virus in mosquitoes occurred after July. While WNV likely circulated at a low level throughout the 2020 mosquito season, the virus was detected in only four of the 16 weeks of MMCD testing (Fig. 2.4). The minimum WNV infection rate in mosquitoes peaked during the week of September 14 at 2.47 per 1,000 mosquitoes tested.

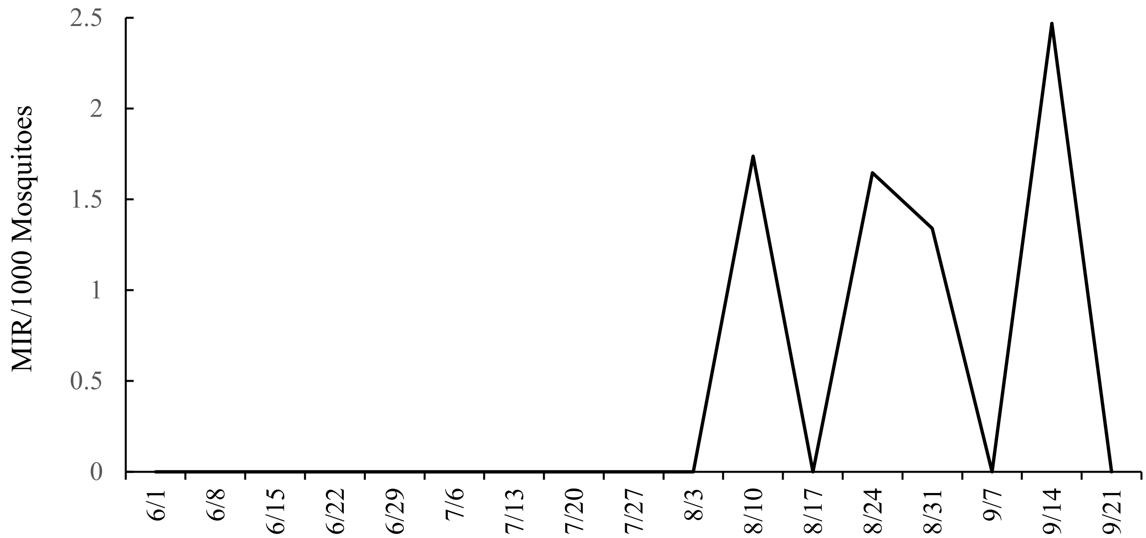


Figure 2.4 Weekly minimum WNV infection rates (MIR) per 1,000 *Culex* specimens tested in 2020. Dates listed are the Monday of each sampling week.

Surveillance for WNV - Birds The District received only 12 reports of dead birds by telephone, internet, or from employees in the field in 2020. Five of the birds reported were corvids, four were American crows and one was a blue jay. All other reports were of non-corvids. No birds were tested by MMCD for WNV in 2020.

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 were low throughout the 2020 season. Weekly mean collections peaked at 0.9 *Cx. tarsalis* per sample on August 24 (Fig. 2.5), the lowest recorded in the District since WNV arrived in 2002. As is typical, few *Cx. tarsalis* were captured by gravid trap in 2020.

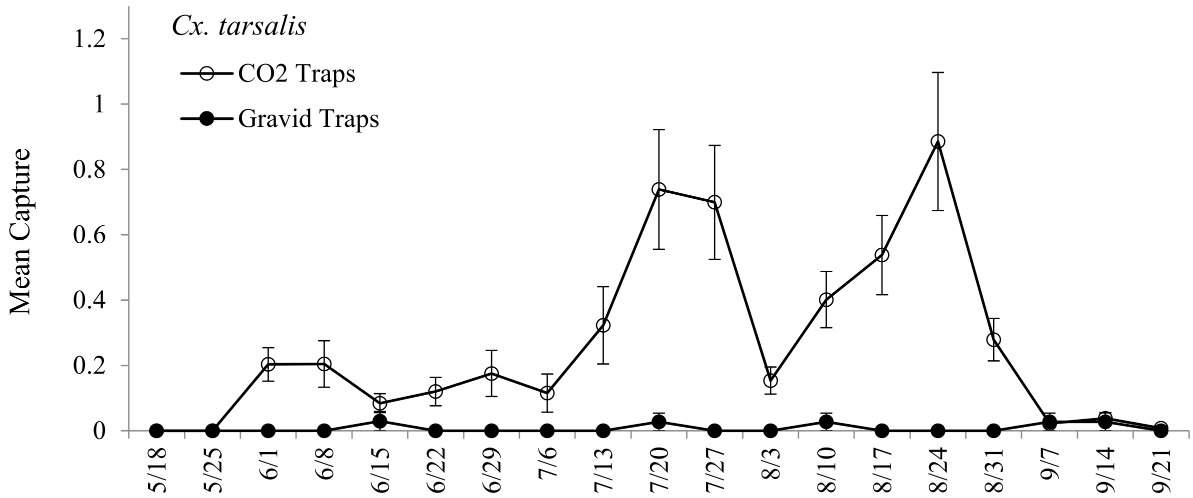


Figure 2.5 Average number of *Cx. tarsalis* in CO_2 traps and gravid traps, 2020. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

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 2020 (Fig. 2.6). The CO_2 trap captures peaked on June 1 at 0.9 per trap. Gravid trap collections of *Cx. restuans* were low to moderate for most of the season. The peak rate of capture occurred during the week of June 15 at 8.0 per trap.

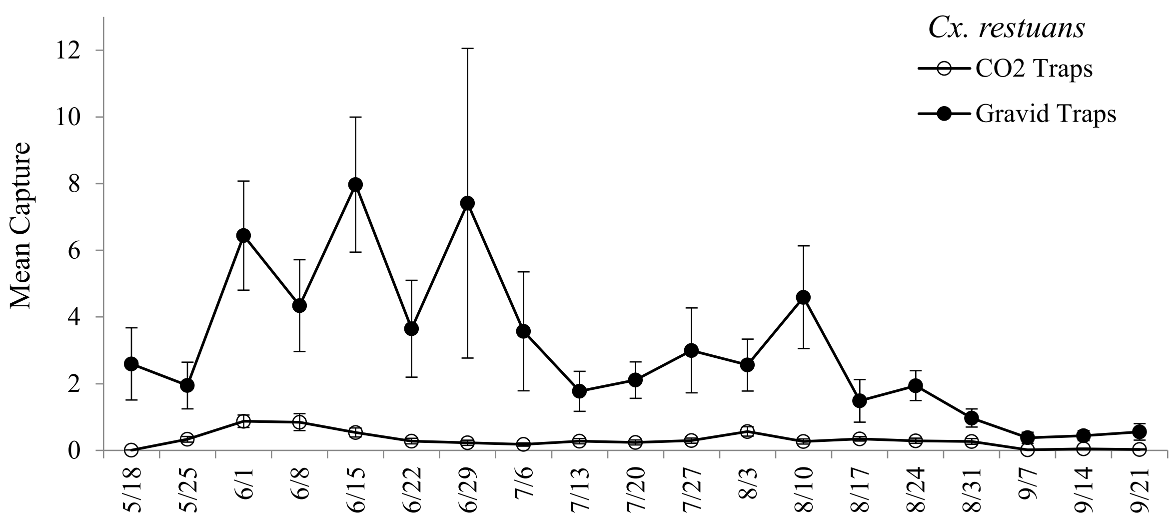


Figure 2.6 Average number of *Cx. restuans* in CO_2 traps and gravid traps, 2020. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

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 2020, collections of *Cx. pipiens* in both CO_2 traps and gravid traps rebounded to moderate levels (Fig.2.7) after very low captures in 2019. The rate of capture peaked at 6.5 per gravid trap during the week of August 10 and at 2.4 per CO_2 trap during the week of August 31.

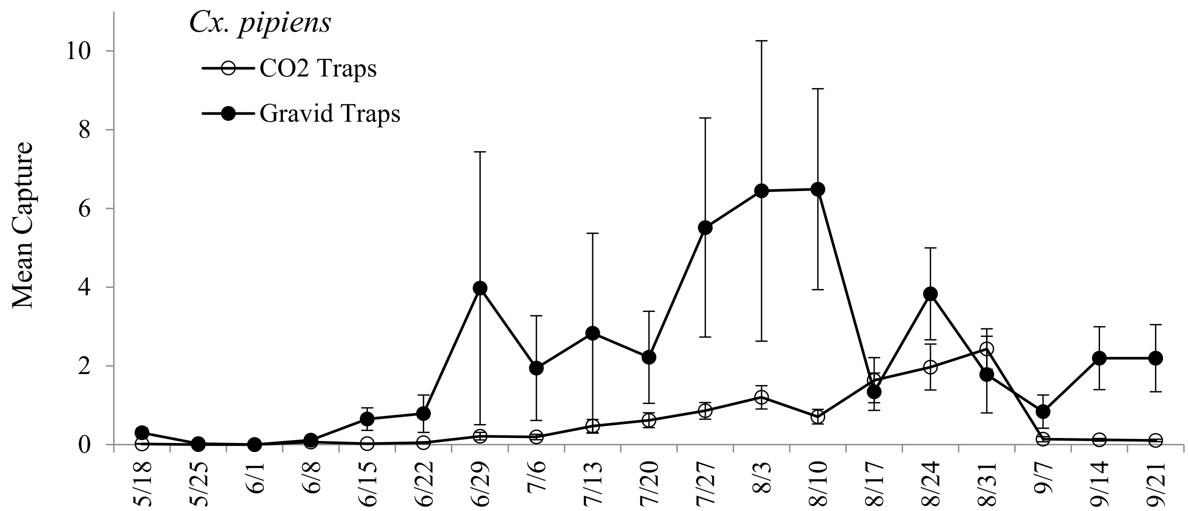


Figure 2.7 Average number of *Cx. pipiens* in CO_2 traps and gravid traps, 2020. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

Often, *Cx. pipiens* and *Cx. restuans* adults are difficult to distinguish from each other. In these instances, they are grouped together and identified as *Cx. pipiens/restuans* (Fig. 2.8). When *Culex* mosquitoes can only be identified to genus level due to poor condition of the specimens, they are grouped as *Culex* species (Fig. 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. Collections of both groups mimicked each other week to week in 2020 and likely consisted of mostly *Cx. restuans* through June and then mostly *Cx. pipiens* thereafter.

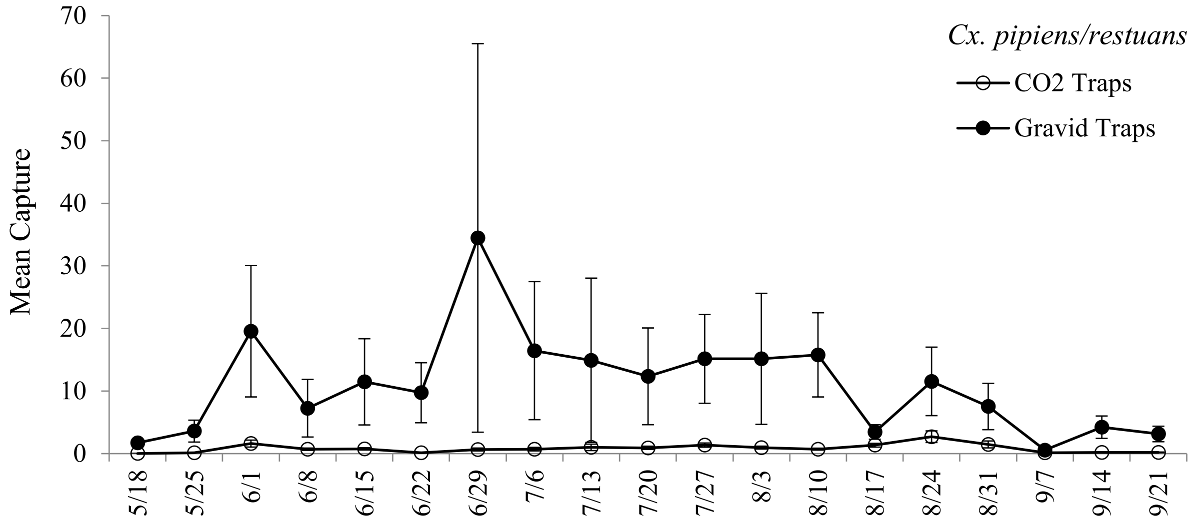


Figure 2.8 Average number of *Cx. pipiens/restuans* in CO_2 traps and gravid traps, 2020. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

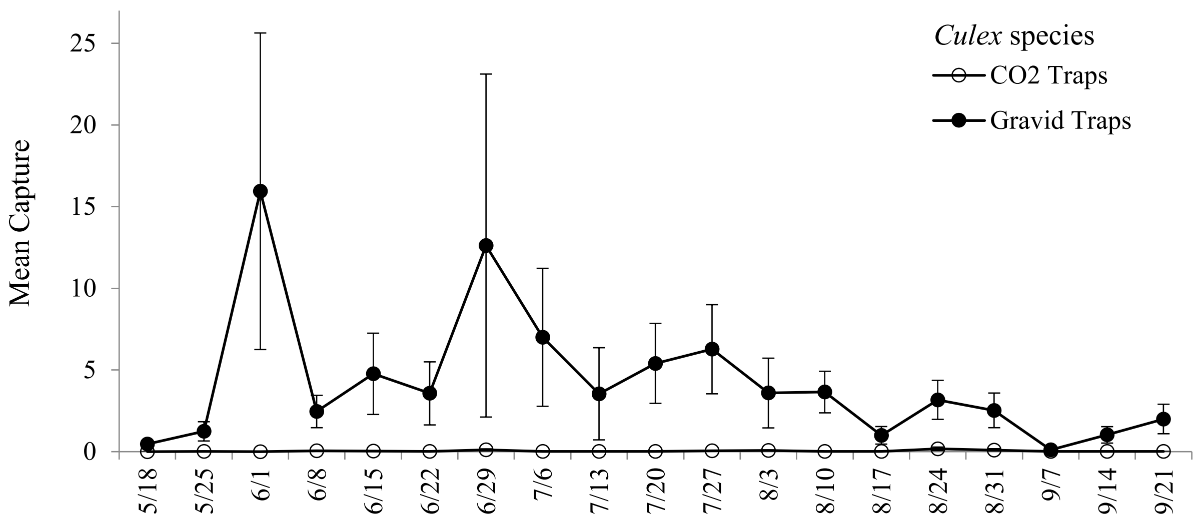


Figure 2.9 Average number of *Culex* species in CO_2 traps and gravid traps, 2020. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

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. Furthermore, in large wetlands larvae can disperse over a wide area or they may clump together in small, isolated pockets. They are generally easier to locate in small habitats (i.e., catch basins, stormwater management structures, etc.) where greater concentrations of larvae tend to be more evenly dispersed.

Stormwater Management Structures and Other 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 404 larval samples from stormwater structures and other constructed habitats. *Culex* vectors were found in 71.0% of the samples in 2020 (Table 2.4). *Culex pipiens* were found more frequently than in 2019. The frequency of *Cx. restuans* collections was at the lower end of the range typically observed for these habitats.

Table 2.4 Frequency of *Culex* vector species in samples collected from stormwater management structures and other constructed habitats from 2016-2020.

	Yearly percent occurrence				
Species	2016 (N=625)	2017 (N=627)	2018 (N=765)	2019 (N=664)	2020 (N=404)
Cx. pipiens	27.4	39.7	46.5	5.4	24.0
Cx. restuans	75.4	60.0	63.7	75.0	59.9
Cx. salinarius	0.0	0.5	0.0	0.0	0.0
Cx. tarsalis	3.5	3.2	1.4	3.2	0.7
Any *Culex* vector spp.	90.1	74.6	81.2	79.7	71.0

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 United States 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 2020, we continued the cooperative mosquito control plan for underground habitats. Sixteen 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 838 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 2020; 838 structures were treated with a total of 961 briquets.

City	Structures treated	Briquets used	City	Structures treated	Briquets used
Arden Hills	15	15	Mendota Heights	18	19
Bloomington	101	118	Minneapolis	175	175
Brooklyn Park	4	15	Moundsview	5	5
Columbia Heights	10	14	New Brighton	5	8
Eden Prairie	12	20	Richfield	13	25
Edina	61	122	Roseville	27	29
Golden Valley	132	132	Shoreview	22	25
Maplewood	235	235	Spring Lake Park	3	4

Larval Surveillance in Catch Basins Catch basin larval surveillance began the week of May 18 and ended the week of September 21. Larvae were found during 628 of 887 catch basin inspections (70.8%) in 2020 (Fig. 2.10).

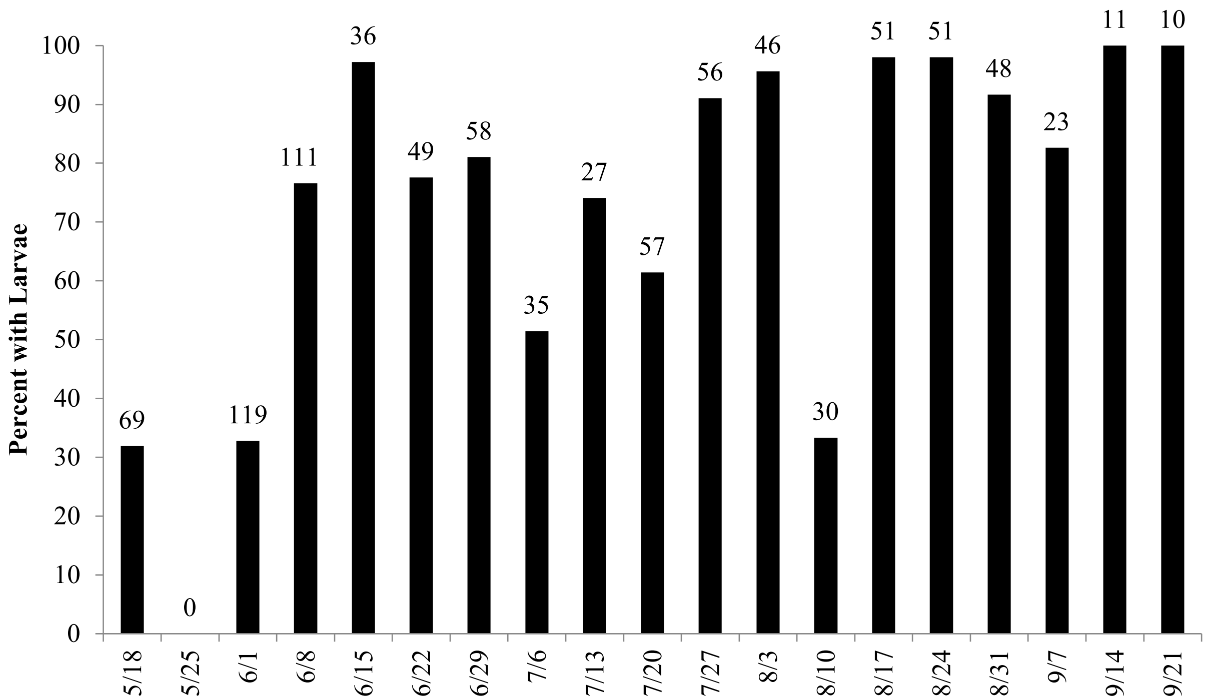


Figure 2.10 Percent of catch basins inspected with mosquitoes present in 2020. Bars are labeled with the number of inspections occurring during the week. Excludes surveillance of sites treated with the larvicide VectoLex® FG.

Mosquito larvae were identified from 1,040 catch basin samples. *Culex restuans* were found in 52.6% of catch basin larval samples. *Culex pipiens* were found in 32.6% of samples. At least one *Culex* vector species was found in 85.0% of samples. *Culex restuans* were collected less frequently in catch basins during most weeks than is typical (Fig. 2.11), while *Cx. pipiens* were collected about three times more frequently than in 2019.

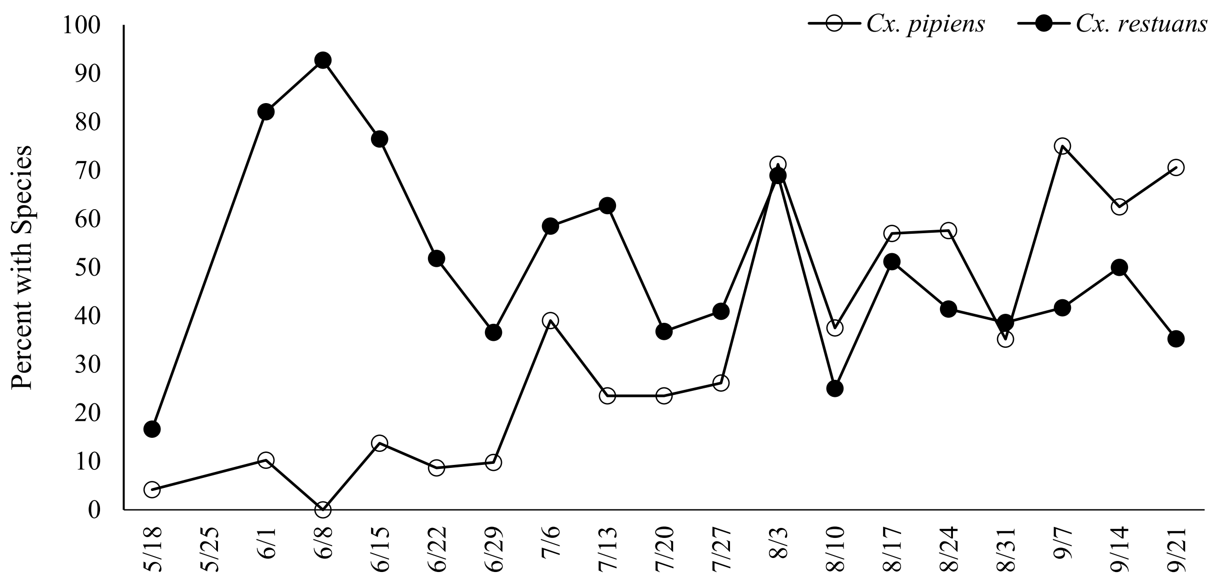


Figure 2.11 Percent occurrence of *Cx. pipiens* and *Cx. restuans* in catch basin larval samples by week. No sampling occurred during the week of May 25.

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 2020, nine human EEE illnesses were reported to CDC from four states. Three of those illnesses were fatal. Wisconsin reported two illnesses in residents of Chippewa and Eau Claire counties. There were veterinary reports of EEE activity in 12 states. A total of 132 EEE illnesses in horses were reported. Nine states reported EEE positive findings from mosquito samples.

Two of the equine EEE illnesses reported in 2020 occurred in Minnesota: one in Aitkin County and one in Benton county. This was the second consecutive year with equine EEE cases in Minnesota.

***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 2020 *Cs. melanura* population while low, increased slightly from 2019 with a season total of only 90 adult females collected in 195 CO_2 trap placements. Nineteen pools containing 126 *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 (Fig. 1.5, p. 8) 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 May 25 (Fig. 2.12). The population remained low throughout the season with a maximum capture of 1.1 per trap on July 13.

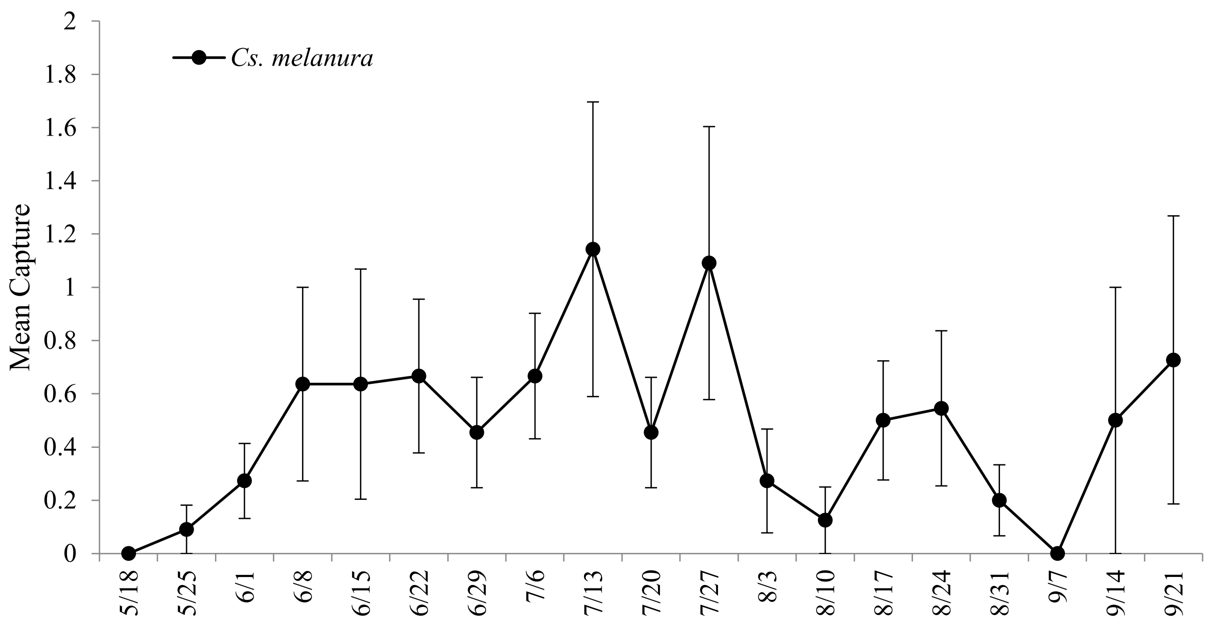


Figure 2.12 Mean number of *Cs. melanura* adults in CO_2 traps from selected sites, 2020. Dates listed are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

Staff collected 352 *Cs. melanura* in 79 aspirator samples from wooded areas near bog habitats. The first aspirator collections of *Cs. melanura* occurred during the week of June 1 (Fig. 2.13). There were four weeks in 2020 when only a single aspirator sample targeting *Cs. melanura* was collected. Three of those captured elevated numbers of the species including a capture of 55 during the week of June 8. For weeks with multiple samples, the peak rate of capture was 8.4 *Cs. melanura* per sample during the week of August 3.

Culiseta melanura develop primarily in bog habitats in the District, and larvae can be difficult to locate. In 2020, *Cs. melanura* larvae were found in four of four sites surveyed for the species.

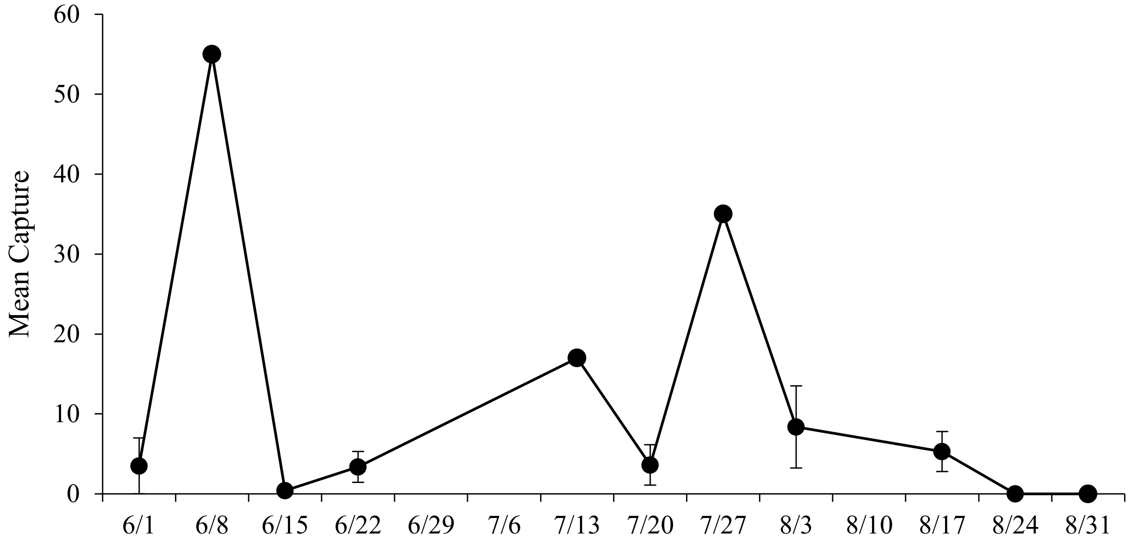


Figure 2.13 Mean number of *Cs. melanura* in 2020 aspirator samples plotted by week. Dates listed are Monday of each week. There were no samples during the weeks of June 29, July 6, and August 10. Single samples were collected during the weeks of June 8, July 13, July 27, and August 31. Error bars equal ± 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. *Culex tarsalis* collections were very low in the District in 2020 (Fig. 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.

There were no JCV illnesses reported in Minnesota in 2020. Only six cases were reported nationally from three states. One of the illnesses was reported in a resident of Wisconsin.

Over the past three seasons, MMCD has partnered with the Midwest Center of Excellence for Vector-borne Disease (MCE-VBD) to investigate JCV transmission in the region. Mosquitoes collected by MMCD have been tested at MCE-VBD for JCV. In 2018, one of 428 and in 2019 one of 336 mosquito samples tested were positive for the virus. Both positive pools were collected in Scandia Township in Washington County. The 2018 positive sample was a pool of *Ae. provocans* and the 2019 positive sample was a mixed pool of banded-legged spring *Aedes* species.

In 2020 we planned for intensified spring *Aedes* larval surveillance in the Scandia area where JCV was detected. Due to COVID-19 restrictions in late March and early April, we were unable to proceed with plans when the targeted species were hatching. We plan to conduct this surveillance in the spring of 2021. We were able to monitor adult mosquito populations in 2020 and we did pool samples for JCV testing. We submitted 88 samples to MCE-VBD, 21 pools of *Ae. provocans* and 67 pools of banded-legged spring *Aedes*. One sample was positive for JCV, consisting of a single *Ae. provocans* collected on June 9 in Ham Lake by aspirator.

2021 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, tire, and container habitat reduction. Eliminating small aquatic habitats will also serve to control populations of *Ae. japonicus*, *Cx. pipiens,* and *Cx. restuans*.

The District will continue to survey aquatic habitats for *Culex* larvae for use in the 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 to reduce WNV amplification.

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

Chapter 3 Tick-borne Disease

2020 Highlights-preliminary

- Number of sites positive for *Ixodes scapularis* was 64
- Average *I. scapularis* per mammal was 1.01
- Found *I. marxi* for the first time in a number of years
- *Amblyomma americanum* 4 reports MMCD, 7 reports MDH (4 reports inside District boundaries)
- Neither 2020 nor 2019 tick-borne cases are available; 2018 Lyme case total: 950 confirmed cases (17 cases per 100,000, source MDH)
- Anaplasmosis cases in 2018 totaled 496 (8.9 cases per 100,000, source MDH)
- One specimen of the non-native *Haemaphysalis punctata* (red sheep tick) found in Rhode Island

2021 Plans

- *I. scapularis* surveillance at 100 sampling locations
- Education, identifications, and homeowner consultations
- Update the Tick Risk Meter, provide updates on Facebook, and post signs at dog parks
- Track collections of *Amblyomma americanum* or other new or unusual tick species, including *Haemaphysalis longicornis*
- Participate in the inter-agency collaboration across MN for *H. longicornis* tracking

Background

Infected *Ixodes scapularis* (also known as the deer tick or blacklegged tick) primarily transmit two important pathogens in our area: Lyme disease, caused by the bacterium *Borrelia burgdorferi*, and human anaplasmosis (HA), caused by the bacterium *Anaplasma phagocytophilum*. Other rare pathogens also cause infection, including Powassan virus and human babesiosis.

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

The original purpose of MMCD's tick surveillance program was to determine the range and abundance of *I. scapularis*. This was achieved by sampling 545 total sites from 1990-1992. Today, we continue to identify and monitor the distribution of deer ticks via a 100-site sampling network, which is a subset of those original sites. In addition, our study allows us to rank deer tick activity throughout the season, to possibly detect new tick species, and to educate us and others so we can better inform people about reducing the risk of contracting a tick-borne illness. All collected data are summarized in a report and presented to the MDH and other agencies for their risk analyses. Additionally, MMCD has collaborated with the University of Minnesota (UMN) and others on spirochete and anaplasmosis studies.

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

2020 Tick-borne Disease Services

Lyme Disease and Human Anaplasmosis

Even through there were changes to MMCD operations brought on by the COVID-19 pandemic, tick surveillance continued as in past years, although additional staff (from St. Paul for a limited time) were utilized.

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 788 was set in 2011. There were 950 confirmed Lyme disease cases (and 591 probable cases) and 496 HA cases (confirmed and probable) in 2018, both lower than in 2017. Case totals from 2019 and 2020 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, *I. scapularis* was detected with greater frequency and they are prevalent now in many wooded areas south of the Mississippi River. The 2020 Lyme Tick Distribution Study report will be available on our website in June (https://mmcd.org/publications/). Following are some preliminary 2020 highlights.

The average number of *I. scapularis* collected per mammal (1.01), excluding 2003 (0.39), 2006 (0.64), 2008 (0.64), 2013 (0.40), and 2019 (0.80), is similar to all of our yearly averages from 2000 (range 1.21-1.68), and higher than all of our averages tabulated from 1990-1999 (range 0.09-0.41) (Table 3.1). Our record high of 1.68 had been tabulated in 2016. In 2020, as in all years from 2007-2019 except for 2011, we had collected at least one *I. scapularis* from all seven counties that comprise our service area. We tabulated 64 positive sites which is similar in number to past years. Our yearly positive site totals from 2000-2009 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. 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 *Ixodes scapularis* per mammal, 1990-2020 (preliminary); 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. scapularis* / 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
2019	1121	1164	280	54	645	181	4	0.80
2020	1109	1264	75	61	1072	49	7	1.01

[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 reduced in 2020 but included tick identifications of emailed or mailed ticks, updating our Tick Risk Meter on our website, and providing tick-borne disease information via telephone and on MMCD's Facebook page. See Additional Updates for more.

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 distribution to various locales was suspended for the 2020 season due to the ongoing pandemic.

Additional Updates – 2020

New Exotic Tick Found in the US The MDH reported to us that the red sheep tick, *Haemaphysalis punctata*, was found in Rhode Island in 2020. This tick species is closely related to the Asian longhorned tick, and like its close relative, is known to have the ability to transmit a number of pathogens that cause tick-borne diseases.

Asian Longhorned Tick (*Haemaphysalis longicornis)* Surveillance Continued The Asian longhorned tick (*H. longicornus*), first detected on a sheep in New Jersey in the fall of 2017, was later determined to have been present in the United States since at least 2010. The type apparently introduced into the US is parthenogenetic (asexual). The implication is that an introduction of a single tick into an area could potentially cause the Asian longhorned tick to become established in that area.

There have been no known introductions of this tick into Minnesota to date.

MMCD continues to participate in an inter-agency collaboration.
Participating agencies are:

- Indian Health Services (northern MN)
- Minnesota Board of Animal Health
- USDA Animal and Plant Health Inspection Service
- Minnesota Department of Health
- Metropolitan Mosquito Control District
- University of Minnesota
- Wildlife Rehabilitation Center of Minnesota

The ongoing plan is that all agencies will continue to keep each other informed of any *H. longicornis* found, and any tentatively identified Asian longhorned ticks will be sent to Dr. Ulrike Munderloh, University of Minnesota – Twin Cities, for confirmation of identifications. Further, the MDH will keep us all informed of the monthly United States Department of Agriculture telemeetings.

MMCD – Asian Longhorned Tick Specific Plans - Ongoing MMCD is in a good position to detect introductions of *H. longicornus* in our service area.

- Staff will continue to turn in any unusual looking adult ticks for identification
- Our tick identification service has been in place for many years; that provides us with a good platform which is being used to encourage the public to turn in ticks for identification
- Since *H. longicornis* immatures are thought not to feed on mice or other small mammals, our tick surveillance study will not detect them; however, performing and discussing our tick surveillance work within the agency keeps us more attuned to ticks and their associated health risks, which theoretically should make us more likely to check for and to notice unusual tick specimens
- MMCD staff will, when COVID-19 restrictions end, again distribute the Asian longhorned tick identification cards (with lone star ticks on the opposite side) to help the public learn what to look for and to assist us in detecting any possible introductions
- MMCD will continue to utilize Facebook to keep the public informed of *H. longicornis* updates and to enlist their help in watching for this tick

***Amblyomma americanum* (lone star tick)** *Amblyomma americanum* is an aggressive human biter and can transmit bacteria that cause ehrlichiosis, among other potential pathogens. Both the tick and ehrlichiosis 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 MDH and MMCD (from Minneapolis and Circle Pines). This trend has continued since, with *A. americanum* submitted to MMCD and/or 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.

Including 2020 submissions, between MMCD and the MDH we have totaled 42 *A. americanum* since 2009. In 2017, MMCD did not receive any reports but MDH received one report each from Hennepin and Washington counties and three additional reports from outside MMCD's service boundaries. In 2018, MDH received a report of one adult (sex unknown), and collected one adult female in Itasca State Park, outside MMCD's service boundaries. MMCD received one adult female *A. americanum* from Shoreview (Ramsey County). In 2019, MMCD collected one adult female in Scott County, and MDH reported one adult female from Washington or Hennepin counties. In 2019, MMCD collected one adult female in Scott County, and MDH reported one adult female from Washington or Hennepin counties.

In 2020, MMCD received four reports while the MDH received seven (one was from outside of Minnesota); all were adult ticks. There were four *A. americanum* (three actual ticks and one emailed picture) reports from inside MMCD boundaries (one adult female each in Dakota, Hennepin (MMCD), Ramsey, and Anoka counties (MDH) and five additional reports (several unverified as they were reported but no actual tick or picture was seen) from outside MMCD's service area (Northfield – unverified female – partially Dakota but mostly Rice County - MMCD), North Mankato (Nicollet) – one adult female MMCD and one adult male MDH - found a 10 minute drive south from MMCD's earlier collection), and also one adult male Douglas County (MDH) and one adult male (unverified report and sex) from Itasca State Park which is located within parts of Clearwater, Hubbard, and Becker counties (MDH). The MDH received a report of a lone star tick that had been collected in the state of Mississippi.

***Rhipicephalus sanguineus* (brown dog tick)** *Rhipicephalus sanguineus* is typically found in warm climates and/or environments, and once introduced into a home, or, more typically in the Midwest, a dog kennel, can quickly build up in population. Specimens are, on occasion, submitted to MMCD or the MDH for identification. In early July 2020, the MDH obtained 24 brown dog ticks from a Hudson, WI resident.

2021 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 of tick identifications, homeowner consultations, updating the Tick Risk Meter on our website, and using social media. Post COVID-19 restrictions we will resume stocking local government agencies, libraries, and other locations with tick cards, brochures, and/or posters, distributing materials at local fairs and the Minnesota State Fair, setting up information booths at events as opportunities arise and will begin re-offering a comprehensive presentation that covers tick biology, diseases transmitted, and prevention measures. We will also continue to post signs 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

***Amblyomma americanum* (lone star tick)** 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.

***Haemaphysalis longicornus* (Asian longhorned tick), Possible Minnesota Introductions**
We will continue to partner with the other Minnesota agencies involved in this effort. All agencies will keep each other informed of any Asian longhorned ticks found, and all ticks will be sent to Dr. Ulrike Munderloh, University of Minnesota – Twin Cities, for confirmation of identifications.

Chapter 4 Mosquito Control

2020 Highlights

- In 2020, 18,676 fewer acres were treated with larvicide (194,911 acres) than in 2019 (213,587 acres)
- We postponed most of our plan to reinstate about one third of the larval control cut in 2017 because of potential levy shortfalls due to COVID-19.
- A cumulative total of 276,517 catch basin treatments were made to control WNV vectors
- In 2020, 15,872 fewer acres of adulticide treatments were made (6,450 acres) than in 2019 (22,321 acres)
- Responding to COVID-19 resulted in 16% fewer seasonal hires because each vehicle can accommodate only one person to maintain social distancing

2021 Plans

- If the economic situation permits, reinstate up to one third of the larval control cut in 2017 as part of the expenditure reduction steps
- Reserve VectoBac® CG for aerial treatments and use other materials for ground treatments to conserve N95 masks (PPE)
- Continue spring *Aedes* larval surveillance in areas with high adult abundance to target potential Jamestown Canyon vectors
- Work closely with the Minnesota Pollution Control Agency 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 (*Coquillettidia perturbans*), several known disease vectors (*Ae. triseriatus, Culex tarsalis, Cx. pipiens, Cx. restuans, Cx. salinarius*), and *Ae. 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 (82,205 potential sites) are scrutinized for all target mosquito species.

Larval habitats are diverse. They vary from 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). We treated a few smaller sites (primarily sites formerly treated when frozen with Altosid® briquets) using a drone (see Chapter 7 for details).

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® FG) 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 2020: 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. Appendices E and F contains a historical summary of the number of acres treated with each control material. Insecticide labels are located in Appendix G.

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.

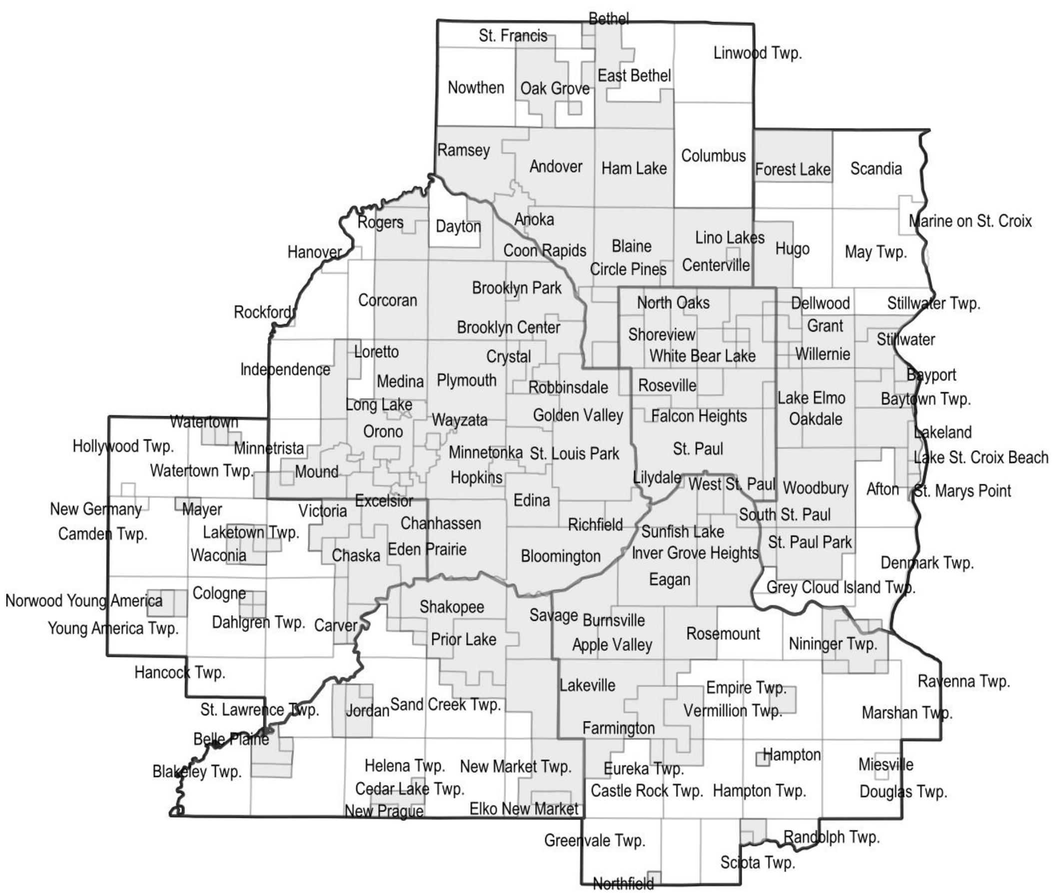


Figure 4.1 Priority zones 1 (shaded-P1) and 2 (white-P2), with District county and city/township boundaries, 2020.

2020 Mosquito Control

COVID-19 Program Impacts

Program Changes in Response to COVID-19-related Budget Limitations Forecasts made in April 2020 predicted that July and December 2020 levy payments to the District could be up to 15% less than planned due to the projected economic impact of the COVID-19 pandemic. In January 2020, we had planned to restore some service reductions implemented in 2017 to reduce expenditures. In April, we began reviewing how our plans needed to be changed to achieve the following goals.

- Provide as many services as possible while maximizing staff and citizen safety by implementing social distancing and all other COVID-19 safety requirements
- Preserve our current cash reserves to insulate the District from negative economic impacts in 2020, 2021, and thereafter

Resource limitations we anticipate include:

- We expect of levy deficit of 10-15% (usual planned deficit is 2%)
- Social distancing restricts us to one employee per vehicle – consequently we hired 16% fewer seasonal inspectors (about 32 seasonal employees) than planned

In order to develop a new spending plan, we started with the January 2020 plans (full levy) including restored services ($400,000) and recent average annual expenditures. These projections indicated that we would quickly spend cash reserves that took three years to build up if we did not change our spending plans. We may not receive a full levy in 2021 either, another reason we should not spend down any cash reserves.

We next determined what expenditure level in 2020 would not impact our reserves. We planned for 85% levy receipts. These forecasts indicated that, if we could keep 2020 expenditures at the 2019 level ($15,933,030), we could preserve our fund balance and cash reserves if we received only 85% of the 2020 levy (Table 4.1). By reviewing the expenditures related to various items including service restorations planned in January 2020, we were able to determine how to limit expenditures to the 2019 level (Table 4.1). We also were able to shift some control materials to maximize the use of cheaper materials (especially for aerial treatments) and retain more expensive materials for use if precipitation was more than typical later in the 2020 season.

We were able to maintain the planned increase in larval cattail mosquito control (the amount of which we know most reliably because spring *Aedes* and summer floodwater are impacted much more by precipitation during the season) and minimize expenditures to the 2019 level if we cancelled the other service restorations (Table 4.1), freeze regular fulltime staff hiring and postpone certain large capital purchases such as scheduled replacement vehicles.

Table 4.1 Control program plans in January 2020 compared to changes implemented in April 2020 in response to predicted levy shortfalls due to the COVID-19 pandemic.

	Jan 2020 Plan	85% 2020 Levy
Expected Levy	$18,534,462	$15,754,293
Planned Expenditure	$17,190,778	$15,962,936
Planned Service Restorations		
Increased Spring *Aedes* (including P2)	Yes	Cancelled
Increased cattail (including P2)	Yes	Yes
Increased summer floodwater (including P2)	Yes	Cancelled

To meet our 2020 expenditure goal, we cancelled all planned service restorations except the increased cattail mosquito treatments, froze regular fulltime staff hiring, and postponed certain large capital purchases such as scheduled replacement vehicles. We also shifted some control materials to maximize the use of cheaper materials (especially for aerial treatments) and conserve our supply of N95 masks.

Program Results The number of acres worth of aerial and ground larval mosquito control completed in 2020 was very similar to 2017 (Table 4.2). The number of seasonal inspectors was lower in 2020, because only one person could use a vehicle to satisfy social distancing requirements. Having fewer inspectors did not impact our ability to complete larval control because of the material choice changes we implemented and the relatively dry weather during 2020. Larval control material changes included decreasing aerial prehatch treatments (especially costlier materials) and reserving *Bti* for aerial treatments to conserve limited N95 mask supplies. We conducted more limited check and treat work in ground sites but used prehatch (again mainly cheaper materials) instead of *Bti* for larval treatments.

Table 4.2 Number of acres treated and number of seasonal inspectors 2016-2020.

	2016	2017	2018	2019	2020
Acres Larval Control	304,682	193,890	187,727	212,172	194,911
Acres Adult Control	82,967	42,012	38,479	22,325	6,450
Seasonal Inspectors	238	234	229	229	184

Adult control was significantly lower in 2020, in part because adult mosquito abundance was lower overall and in part because fewer inspectors were available. Nighttime cold fogging was impacted the most (Table 4.9).

Our expenditures reduction strategy for 2020 successfully restrained expenditures below our target of $15,933,030. We forecast spending about $1,500,000 less than our target by the end of December, 2020. This is primarily due to savings in the following expense items.

- Regular fulltime employee salaries were lower due to not filling a vacant full-time position and reduced overtime

- Seasonal inspector salaries were lower due to hiring fewer seasonal inspectors and less overtime
- Control material costs were lower because we preferentially used cheaper larvicides for large acre (mostly aerial) treatments
- Helicopter costs were lower because of fewer aerial treatments due to dry weather
- Capital expenses were lower because we delayed large cost purchases

Next Steps to Prepare for 2021 We plan the following steps in late 2020 and early 2021 to continue working to balance District funding and expenditures and to maintain reserves to a level that adequately supports District cash flow needs.

- Purchase some larger capital items (e.g., replacement vehicles, facilities maintenance items) before the end of 2020, items that otherwise would be purchased in 2021
- Carry over more control materials so we need to buy less next year, especially if the economic situation in 2021 still is unfavorable
- Review the economic situation by April 2021 to determine how to continue the District's longer-term plan to bring the levy and budget into parity
- Based upon how we decide to proceed with the District's longer-term plan, determine if we have the funding to restore some services cut in 2017

Larval Mosquito Control

Thresholds and Control Strategy Larval surveillance occurs prior to treatments, and control materials are applied when established treatment thresholds are met, as appropriate. Ground treatments and cattail site treatments are based on presence/absence criteria. For treatments by air, larval numbers must meet treatment thresholds. Table 4.3 displays the treatment thresholds established for each species group and priority zone. The threshold is the average number of larvae collected in 10 dips using a standard four-inch diameter dipper. P1 and P2 areas can have different thresholds to help focus limited time and materials on productive sites near human population centers.

Table 4.3 Air site larval thresholds by priority zone and species group in 2020.

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*

Control for a season begins in the fall of the previous year when we survey cattail sites for larvae of the cattail mosquito, *Cq. perturbans*. Some sites are treated with VectoLex® (*Bacillus sphaericus*) then to eliminate larvae before they overwinter. Some sites where *Cq. perturbans* 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 and Altosid® P35) 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 2020 control material use table).

Spring *Aedes* tend to be long-lived, are aggressive biters, and can lay multiple egg batches. Consequently, they have a lower treatment threshold than summer *Aedes* (Table 4.3), which typically lay only one batch of eggs. In 2018, the spring *Aedes* threshold was raised from 0.5 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 (JCV) vectors, were much higher. After mid-May, when most larvae found are summer floodwater species, the summer *Aedes* threshold is used – 2/dip in P1 and 5/dip in P2 (Table 4.3). The *Culex*4 (*Cx. restuans*, *Cx. pipiens*, *Cx. salinarius*, *Cx. tarsalis*) threshold is 2 in both priority zones (Table 4.3). 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.

Some sites that have a sufficient history of floodwater *Aedes* larval presence are treated with controlled release materials formulated to apply before flooding (“pre-hatch”). This allows staff more time to check and treat other sites after a rainfall. The first ground and aerial prehatch treatments (Natular® G30, Altosid® pellets, Altosid® P35, MetaLarv® S-PT) were applied in mid-May with a second in mid-June and a third in mid-July.

Season Overview In 2020, we were unable to continue expanded larval spring *Aedes* surveillance into P2 areas with higher past adult abundance because of a two-week delay in seasonal inspectors starting work because of the COVID-19 pandemic. Staff detected the first spring *Aedes* larvae on March 16, 20 days earlier than 2019 (April 5) and 39 days earlier than in 2018 (April 24). Aerial *Bti* treatments to control the spring *Aedes* brood began on May 6, four days later than in 2019 and four days earlier than in 2018. 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 two large and eleven small-medium broods of *Ae. vexans* (a typical season has four large broods).

Aerial pre-hatch treatments (Natular® G30, Altosid® P35) to control floodwater *Aedes* were applied in late May and late June. Significantly fewer acres were treated aerially for floodwater *Aedes* with pre-hatch (Table 4.4) as part of the cost reduction steps implemented in responses to COVID-19. The majority of aerial treatments to control cattail mosquitoes using MetaLarv® S-PT and Altosid® P35 were applied the last six days of May and the first three days of June (Figure 4.2); VectoLex® FG was applied September 2-11 to control the overwintering larval cattail mosquito population. Altosid® pellet use was much reduced in 2020 because we replaced it with Altosid® P35. We can apply Altosid® P35 at a lower dosage aerially than Altosid® pellets which enabled us to treat more acres because the per pound cost of Altosid® pellets and Altosid® P35 is similar. VectoLex® FG use (September aerial cattail site treatments) was lower in 2020 (Table 4.4) because we purchased less of this more expensive material as part of cost saving strategy in 2020.

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 2019 and 2020 (research tests not included).

	2019		2020	
Habitat and material used	Amount used	Acres treated	Amount used	Acres treated
Wetlands and structures				
Altosid® briquets (cases)	222.81	162	228.33	180
Altosid® pellets (lb)	33,706.80	12,020	1,826.02	729
Altosid® P35 (lb)	0.00	0	72,890.39	26,784
MetaLarv® S-PT (lb)	67,945.30	23,003	54,195.22	18,408
Natular® G30 (lb)	87,603.72	17,276	44,465.35	8,946
VectoLex® FG (lb)	72,037.95	5,036	27,430.76	1,858
VectoBac® G (lb)	880,675.13	155,735	676,175.40	138,006
Total wetland and structures		213,232		194,911
	Amount used	No. CB treatments	Amount used	No. CB treatments
Catch basins				
Altosid® briquets (cases)	2.16	476	2.14	470
Altosid® pellets (lb)	2,098.52	265,915	2,107.79	264,399
Altosid® P35 (lb)	0.00	0	98.47	11,648
Total catch basin treatments		266,391		276,517

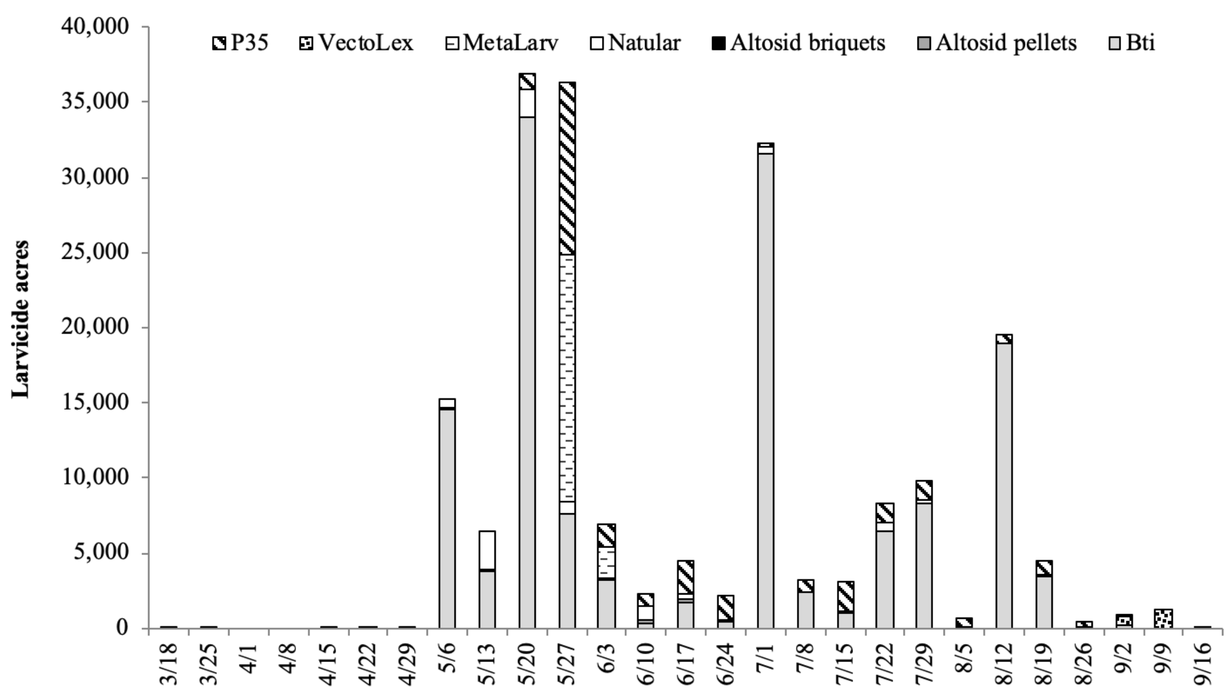


Figure 4.2 Acres treated with larvicide each week (March – September 2020). Date represents start date of week.

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 – Supporting Work).

Cattail Mosquito Control Reduction Evaluation In 2018 through 2020, some control materials were shifted to cattail treatments to maximize treatment in P1. Cattail mosquito larvicide treatments in P2 largely were not applied in 2017 as part of a strategy to reduce expenditures. Relatively limited treatments were resumed in a few local areas within P2 in 2020. Larval surveillance in late 2017 detected more sites containing cattail mosquito larvae in P1 than could be treated in spring 2018 with available resources. A similar number of acres containing cattail mosquito larvae were detected in late 2018. In 2018, larvicides were shifted from floodwater pre-hatch to treat more cattail sites, but available resources still were insufficient. All available resources were used in P1 in 2019. In 2020, acreage requiring treatment was a bit lower in P1 which enabled us to treat a relatively small amount of P2, mainly a few areas near P1.

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 drier conditions in in 2018 through 2020 reduced water levels (and *Cq. perturbans* larval habitat) in many cattail sites. We compared adult cattail mosquito abundance in groups of CO_2 traps in P1 (cattail larvicide treatments maintained in 2016-2020) and P2 (limited cattail larvicide treatments completed in 2016, largely curtailed in 2017-2020) in Washington and Hennepin counties (Figure 4.3). Abundance in traps located in Linwood Township in Anoka County (no cattail mosquito control in 2016-2020) served as a reference (Figure 4.3).

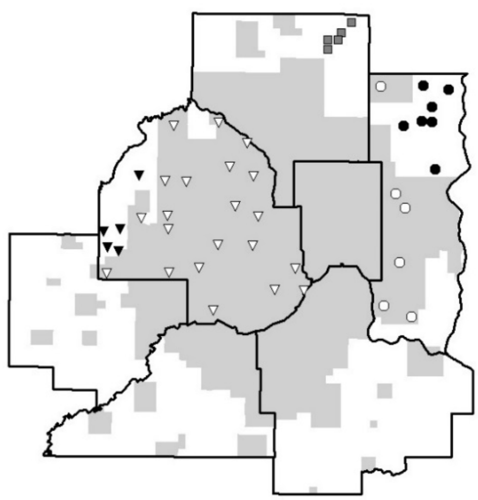


Figure 4.3 Location of CO_2 traps in Hennepin County (P1 white triangles, P2 black triangles), Washington County (P1 white circles, P2 black circles), and Anoka County (Linwood Township) (gray squares). P1 is shaded light gray.

Adult *Cq. perturbans* abundance as measured by CO_2 trap captures in 2016-2020 documented a large increase in 2017 throughout the District; abundance decreased in all five areas in 2018 compared to 2017 (Table 4.4). In 2016, 2017, 2018, 2019, and 2020, abundance was lower in P1 than in P2 in Hennepin and Washington counties (Table 4.5) suggesting that widespread larval control is lowering adult *Cq. perturbans* abundance in P1. The change in adult *Cq. perturbans* abundance each year was less variable in P1 suggesting that widespread larval control effectively suppressed *Cq. perturbans* abundance in 2016 through 2020. The environmental impact of high precipitation in 2014, 2015, and 2016 and lower overall precipitation in 2017 through 2020 seems to have more strongly affected *Cq. perturbans* abundance in P2. In 2016 through 2020, a much larger proportion of cattail mosquito production acreage in P1 was treated with larvicide compared to P2. When environmental conditions support high larval *Cq. perturbans* abundance, a greater proportion of acreage probably will require wide-scale larval control to more significantly decrease adult *Cq. perturbans* abundance.

Table 4.5 Adult *Coquillettidia perturbans* mean abundance in Monday Night Network CO_2 trap annual collections (2016-2020) in five groups of CO_2 traps [mean (± 1 SE)]; P1 and P2 are priority treatment zones, n=number of CO_2 traps, F=full, N=no control, and L=limited control is the control status.

	Hennepin Co.		Washington Co.		Anoka Co. Linwood Twp.
	P1 (n=21)	P2 (n=5)	P1 (n=6)	P2 (n=7)	P2 (n=5)
Year					
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
2019	18.5 (±5.3) F	257.3 (±200.9) N	47.2 (±27.8) F	197.5 (±53.6) N	210.0 (±48.0) N
2020	50.3 (±11.6) F	185.2 (±69.3) N	48.8 (±13.9) F	355.5 (±66.1) N	297.0 (±64.9) N

Coquillettidia perturbans predictions for 2021 (Chapter 1: Surveillance) suggest lower abundance of this species as compared to 2020. Thus, we expect to need to treat fewer acres in P1 in 2021 compared to 2020, potentially enabling us to increase treatments in P2.

Spring *Aedes* Control Strategy Larval surveillance for spring *Aedes* was first expanded in 2018 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 2020, we maintained the P1 spring *Aedes* larval threshold raised in 2018 from 0.5 to 1.0 larva per dip to treat sites that contained higher concentrations of larvae (in both P1 and P2). In 2020, we treated fewer acres for spring *Aedes* than in 2017, 2018 and 2019. No treatments were made in P2 in 2020 largely because fewer staff were hired starting two weeks later than originally planned due to the COVID-19 pandemic (Table 4.6).

Table 4.6 Aerial *Bti* treatment-acres to control spring *Aedes* in P1 and P2 in 2017, 2018, 2019, and 2020.

	Number of acres treated by year			
Priority area	2017	2018	2019	2020
P1	26,204.57	18,044.52	31,146.39	18,304.36
P2	11.86	2,785.85	874.58	0.00
Total	26,216.43	20,830.37	32,020.97	18,304.36

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 2016-2020. Hennepin P1 and Washington P1 are areas where aerial *Bti* treatments targeting spring *Aedes* were completed from 2016-2020. Limited aerial *Bti* treatments were conducted in Hennepin and Washington P2 in 2016; these treatments were not made in 2017, limited treatments were completed in 2018 and 2019 followed by no treatments in 2020. No significant aerial *Bti* treatments targeting spring *Aedes* were completed from 2016-2020 in Linwood Twp. (Anoka County).

Low and variable numbers of adult spring *Aedes* were captured by CO_2 traps which made evaluating change challenging (Table 4.7). Spring *Aedes* abundance in 2016 through 2020 in Hennepin P1 and Washington P1 was essentially equal for all five years; mean abundance each year differed by less than yearly variability (1 SE). Spring *Aedes* abundance was higher in 2019 in Hennepin P1 and Washington P1 but still within variability limits. Yearly spring *Aedes* abundance in Hennepin P2 and Washington P2 was much more variable. Abundance in P2 appeared higher in 2019 than in 2016, 2017, and 2020, especially in Washington County, although variance also was much higher in 2019. Spring *Aedes* abundance in Linwood Township was higher each year than in Hennepin P1 and Washington P1 and similar to Washington P2 in all years after 2017 (Table 4.6). The lower less variable spring *Aedes* abundance in Hennepin P1 and Washington P1 in all five years suggests that widespread larval control is effectively suppressing spring *Aedes*.

Table 4.7 Adult spring *Aedes* mean abundance in Monday Night Surveillance CO_2 trap annual collections (2016-2020) in five groups of CO_2 traps [mean (± 1 SE)]. P1 and P2 are priority treatment zones, n=number of CO_2 traps, F=full, N=no control, and L=limited control is the control status.

	Hennepin County		Washington County		Anoka Co. Linwood Twp.
Year	P1 (n=21)	P2 (n=5)	P1 (n=6)	P2 (n=7)	P2 (n=5)
2016	0.8 (±0.5) F	3.7 (±1.8) L	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
2019	2.9 (±1.3) F	13.6 (±7.5) L	2.8 (±0.9) F	38.0 (±15.1) L	22.7 (±4.5) N
2020	0.9 (±0.4) F	2.1 (±7.5) N	1.2 (±0.6) F	18.1 (±15.1) N	14.3 (±2.3) N

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 4.8). 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 4.8 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 are disease vectors. A blank cell means no threshold established for that 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 2020, adult mosquito levels rose in early June through late-July; at those times, counts over threshold were fairly widespread (Figure 4.4). In 2020, MMCD applied 15,872 fewer acres worth of adulticides than in 2019 in part because fewer inspectors were available. Nighttime cold fogging was impacted the most (Table 4.9, Appendix E). Adult mosquito control was low all season with its greatest peak in late July followed by another smaller peak in early September (Figure 4.4). Nighttime ULV treatments were impacted the most in part because only one employee could be in a vehicle to maintain social distancing (sumithrin and etofenprox in Figure 4.4). The majority of adulticide treatments targeted vector mosquitoes.

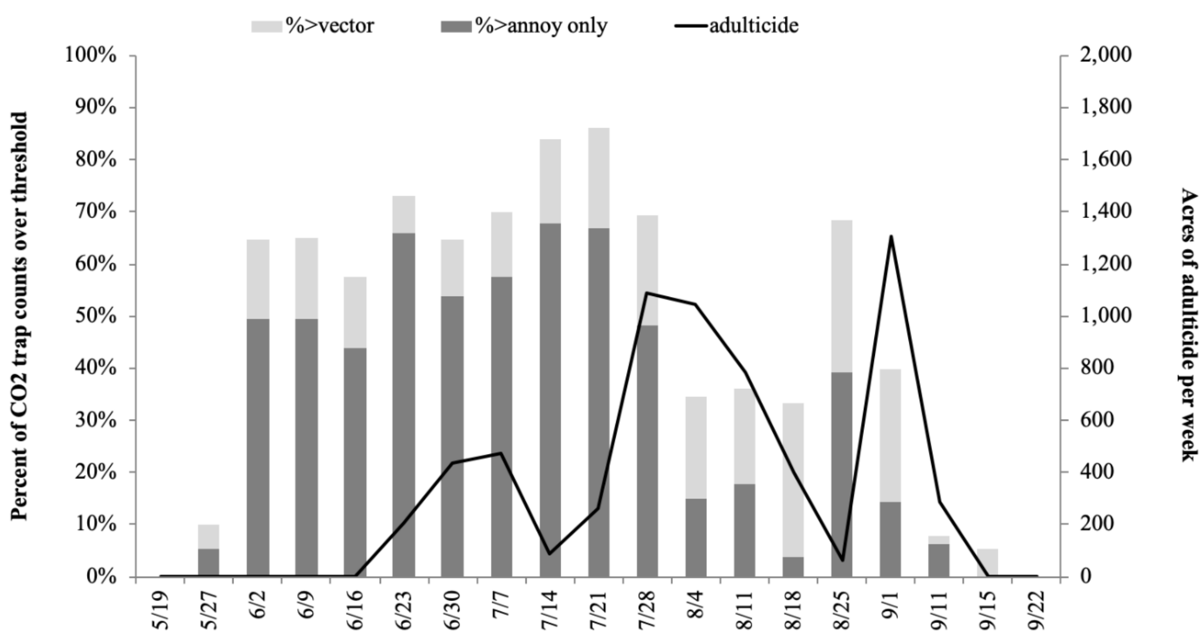


Figure 4.4 Percent of Monday CO_2 trap locations with counts over threshold compared with acres of adulticides applied in 2020 (solid line). Dark bars indicate the percentage of traps meeting annoyance mosquito thresholds and lighter bars represent the percentage of traps meeting the vector thresholds (*Culex*4, *Ae. triseriatus*, *Ae. japonicus*, *Cs. melanura*) on each sampling date. Date is day of CO_2 trap pick up.

Table 4.9 Comparison of adult control material usage in 2019 and 2020.

	2019		2020	
Material	Gallons used	Acres treated	Gallons used	Acres treated
Permethrin	596.40	3,367	306.56	1,742
Sumithrin*	92.12	3,665	13.74	584
Etofenprox*	183.73	15,289	51.62	4,124
Total		22,321		6,450

* 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.

2021 Plans for Mosquito Control Services

Integrated Mosquito Management Program

In 2021, 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, maximizing mosquito control services given available resources (includes reinstating some services cut in 2017 to save money), 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 2021 will remain the same as in 2020.

Larval Control

Temporary Measures to Decrease Expenditures In 2021 (if economic conditions permit), we plan to restore by up to one third, service reductions first implemented in 2017 to save money. Because of a slight overall decrease of acreage meeting larval threshold for the cattail mosquito treatment observed by larval surveillance District-wide in late 2020, we plan to allocate more resources for cattail mosquito control in P2 in 2021. We anticipate no COVID-19 related delay in hiring seasonal inspectors in 2021 meaning we should be able to increase earlier season spring *Aedes* surveillance and larval control.

Floodwater Mosquitoes The primary control material will again be *Bti* corn cob granules. Larvicide needs in 2021, mainly *Bti* (VectoBac® G), Altosid® P35, Natular® G30, and MetaLarv® S-PT, are expected to be similar to the five-year average larvicide usage (219,767 acres). In 2021, we plan to continue the spring *Aedes* larval threshold used in 2020 (1 per dip in both P1 and P2) and consider expanding 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 5 lb/acre and maintain this *Bti* dosage when we switch to the summer *Aedes* threshold.

If we cannot acquire additional N95 masks, *Bti* (VectoBac® G) will be reserved for aerial treatments with other larval control materials used in ground sites. 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 Natular® G30, methoprene products (Altosid® P35, Altosid® briquets, MetaLarv® S-PT), or *Bti* (VectoBac® G) (if more N95 masks are available). 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 2020 (Table 4.3).

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® P35. 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 Altosid® P35 treatments by June 25 with subsequent Altosid® P35 treatments every 30 days thereafter.

Cattail Mosquitoes In 2021, control of *Cq. perturbans* will use a strategy similar to that employed in 2020. 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® P35 and MetaLarv® S-PT to minimize per-acre treatment costs. Beginning in late May, staff will apply Altosid® P35 (3 lb/acre) and MetaLarv® S-PT (3 lb/acre) aerially and by ground. Staff will complete late summer VectoLex® FG 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 2021 are expected to be similar to the five-year average adulticide usage (38,145 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 including 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

2020 Highlights

- Treated 29 small stream sites with *Bti* when the *Simulium venustum* larval population met the treatment threshold; a total of 43.1 gallons of *Bti* was used
- Made 72 *Bti* treatments on the large rivers when the larval population of the three target species met the treatment threshold; a total of 4,042 gallons of *Bti* was used
- Monitored adult populations using overhead net sweeps and CO_2 traps; the average black fly/overhead sweep count was 0.88
- COVID-19 health and safety protocols had minor impacts on population monitoring and sample processing; *Bti* treatment of larval populations that met threshold was not affected

2021 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
- Continue monitoring *Simulium tuberosum* larval and adult populations to better understand its distribution and abundance
- Finish processing 2019 Mississippi River non-target monitoring samples and complete the study report

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 188 small stream and 29 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.

2020 Program

Small Stream Program: *Simulium venustum* Control

Simulium venustum is a human-biting black fly species that develops in small streams in the MMCD area and 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 conducted between late-April and mid-May. A total of 53 monitoring samples were collected using MMCD's standard sampling technique. Fewer small stream monitoring samples than normal were collected in 2020 because of COVID-19 protocols in place. Priority was placed on sampling sites with a known history of meeting the *S. venustum* treatment threshold. Twenty-nine sites on nine streams met the treatment threshold of 100 *S. venustum* per sample that was established in 1990. Sites that met the threshold were treated once with VectoBac® 12AS *Bti*. A total of 43.1 gallons of *Bti* was used for the treatments in 2020 (Table 5.1). In comparison, the

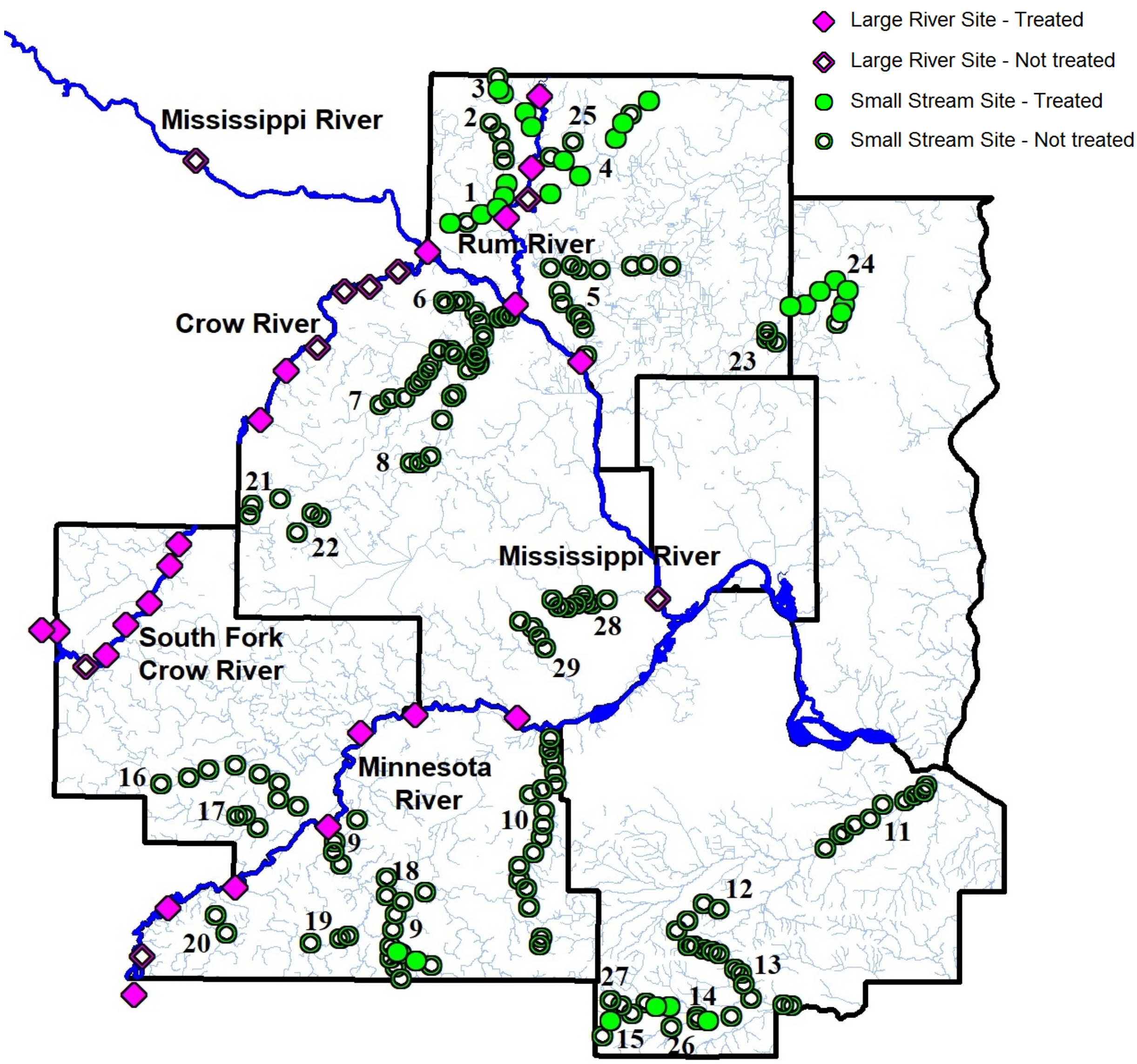


Figure 5.1 Large river and small stream black fly larval monitoring and treatment locations, 2020.

Note: the large river site located outside the District on the Mississippi River is for monitoring only. Since 1991, more than 450 of the 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	7=Rush	13=Chub N. Br.	19=Raven W. Br.	25=Ditch 19
2=Ford	8=Elm	14=Chub	20=Robert	26=Chub Trib. 1
3=Seelye	9=Sand	15=Dutch	21=Pioneer	27=Dutch Trib. 1
4=Cedar	10=Credit	16=Bevens	22=Painter	28=Minnehaha
5=Coon	11=Vermillion	17=Silver	23=Clearwater	29=Nine Mile
6=Diamond	12=Vermillion S. Br.	18=Porter	24=Hardwood	

average amount of *Bti* used to treat small stream sites annually during 1996-2019 was 27.7 gallons. High spring stream flows contributed to the increased amount of *Bti* used in 2020.

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, Crow, and South Fork 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 May and mid-September using artificial substrate samplers (Mylar tapes) at the 29 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.

A total of 476 larval monitoring samples were collected from the large river sites in 2020. The treatment threshold was met in 72 samples from 22 of the permitted sites; the associated sites were treated with a total of 4,042.0 gallons of VectoBac® 12AS *Bti* (Table 5.1). The average amount of *Bti* used for the large river treatments annually between 1996 and 2019 was 3,245.4 gallons. The average number of treatments each year during this same period was 63.4 (Table 5.1). The amount of *Bti* used in 2020 was nearly 800 gallons more than the long-term average amount used when the treatment thresholds were met. The reason more *Bti* was used in 2020 was primarily due to the control of *S. meridionale* on the Minnesota River (Table 5.1).

Table 5.1 Summary of *Bti* treatments for black fly control by the MMCD in 2020 versus long-term average.

	2020			Long-term Average[1]		
Water body	No. sites treated	Total No. treatments	Gal. of *Bti* used	No. sites treated	Total No. treatments	Gal. of *Bti* used
Small Stream	29	29	43.1	45.0	45.0	27.7
Large River						
Mississippi	2	10	824.0	2.1	10.8	1,187.2
Crow	2	5	82.5	2.2	5.2	97.3
S. Fork Crow	7	10	82.5	5.5	12.0	109.2
Minnesota	7	23	2846.7	5.9	16.0	1,708.2
Rum	4	24	206.3	3.3	19.4	143.5
Large River Totals	22	72	4,042.0	19.0	63.4	3,245.4

[1] The Mississippi, Crow, Minnesota, Rum and small stream averages are from 1996-2019. The South Fork Crow average is from 2005-2019.

Flow on the Minnesota River ranged between 7% and 74% above average (average = 54%) between April and July in 2020. These are the months when *S. meridionale* larvae are most abundant in the river. The higher flows during this time period likely led to an increase in the amount of suitable larval habitat in the river resulting in an increase in *S. meridionale* production. The treatment threshold for *S. meridional*e was met 23 times (at multiple treatment sites) between May and July in 2020. This was seven more treatments than the long-term average number of treatments done since 1996 on the Minnesota River (Table 5.1). Because the amount of *Bti* required to achieve the proper concentration for effective control is directly proportional to flow, larger volumes of *Bti* were also required for the treatments.

The efficacy of the VectoBac® 12AS treatments was measured by determining larval mortality 250 m downstream from the *Bti* application point following most treatments in 2020. Overall, the average black fly larval mortality was excellent in 2020. Post-treatment mortality was 100% on the Minnesota River, 97% on the Rum River, 98% on the Crow River, 98% 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 54 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 2020 was 0.88 (± 6.76 SD). In comparison, the average of all species captured in net sweeps from 1996 (the start of operational *Bti* treatments) to 2019 was 1.29 (± 0.80 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).

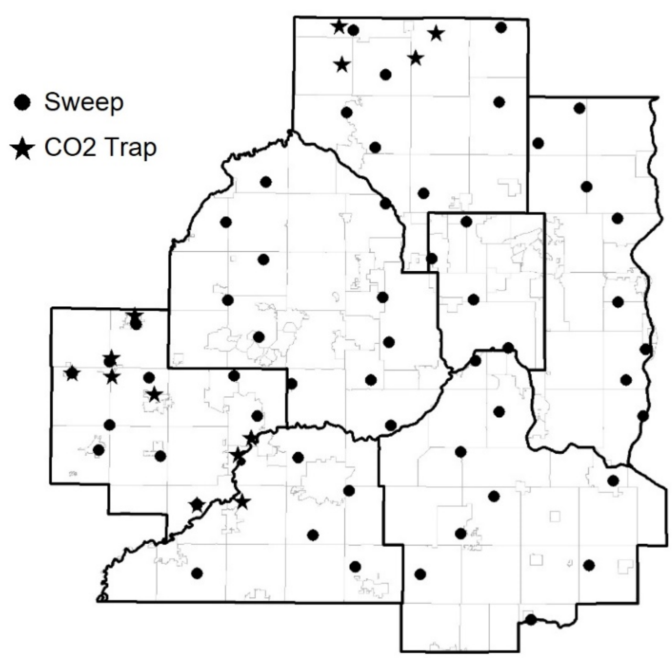


Figure 5.2 Adult black fly sweep and CO_2 trap sampling locations, 2020.

The county with the highest number of total black flies captured in the sweep net monitoring samples was Hennepin County where a mean of 2.91 (± 14.80 SD) per sample for all species was recorded. The county with the second highest sweep net count for total black flies was Anoka County where the mean was 0.48 (± 1.37 SD) per sample. Dakota County was the third highest county for the net sweep count of total black flies with a mean of 0.41 (± 1.58 SD) per sample.

The most abundant black fly species collected in the overhead net-sweep samples in 2020 was *S. luggeri*, comprising 66.6% of the total black fly adults captured with an average of 0.58 (± 6.56 SD) per sample. The second most abundant black fly species captured was *S. meridionale,* comprising 18.5% of the total with an average of 0.16 (± 0.92 SD) per sample (Table 5.2). The third most abundant black fly species captured in 2020 was *S. tuberosum,* comprising 7.8% of the total with an average of 0.07 (± 0.59 SD) specimens per sample. This was the largest number of *S. tuberosum* that has been collected in the net sweep samples since sampling began in 1984.

Simulium luggeri was most numerous in Hennepin and Anoka County net sweep samples. The mean number of *S. luggeri* per sample was 2.47 (± 14.54 SD) in Hennepin County and 0.39 (± 1.27 SD) in Anoka County. *Simulium meridionale* was most abundant in the Carver County samples with a mean of 0.25 (± 1.43 SD) per sample. Washington County had the second highest count of *S. meridionale* with a mean of 0.22 (± 0.82 SD). *Simulium tuberosum* was most abundant in the Hennepin County samples with a mean of 0.15 (± 1.03 SD) per sample. The county with the second highest sweep count for *S. tuberosum* was Dakota County, where the mean was 0.13 (± 0.79 SD) per sample.

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	1996-2019	1.29 ± 0.80	0.96 ± 0.77	0.01 ± 0.01	0.21 ± 0.27
	2020	0.88 ± 6.76	0.58 ± 6.56	0.00 ± 0.00	0.16 ± 0.92

[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 South Fork Crow River.
[5]All species includes *Simulium luggeri*, *S. meridionale*, *S. johannseni*, and all other black fly species collected.

Black Fly-Specific CO_2 Trap Collections Adult black fly populations were monitored from mid-May through June in 2020 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 have been monitored with CO_2 traps since 2004. Due to the District's COVID-19 health and safety protocols CO_2 trapping was done once per week in 2020 compared to twice weekly as in past years. Black flies captured in the CO_2 traps are preserved in alcohol to facilitate species identification.

A total of 40,310 black flies were captured in the CO_2 traps in 2020. The most abundant species captured was *S. meridionale* with a total of 35,855 specimens which comprised 89% of the total black flies collected in the CO_2 traps. *Simulium johannseni* was the second most abundant species collected with a total of 2,634 specimens which comprised 6.5% of the total. The third most numerous species collected was *S. venustum* with a total of 1,361 specimens that comprised 3.4% of the total. A very small number of *S. tuberosum* was also captured in the CO_2 traps. A total of 56 specimens that comprised 0.14% of the total were collected. Table 5.3 lists the mean number of *S. meridionale*, *S. johannseni,* and *S. venustum* captured in the CO_2 traps since the trapping program began in 2004.

Table 5.3 Mean number of adult *Simulium venustum*, *S. johannseni*, and *S. meridionale* captured in CO_2 traps set weekly between May and mid-June in Anoka, Scott, and Carver counties, 2004-2020[a].

	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[b]	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
2018	9.79	3.87	4.94	0.00	4.09	280.79	1.36	160.06	436.58
2019	6.89	6.72	0.48	0.53	2.43	3.70	2.36	11,347.24	3,318.10
2020	8.15	40.25	0.41	0.26	5.36	72.85	2.26	386.04	734.85
SD	±21.00	±182.63	±1.33	±1.16	±16.24	±198.29	±3.32	±798.19	±2,279.87
No. Traps	4	4	5	4	4	5	4	4	5

[a]Traps were set twice per week between 2004–2019; in 2020 they were set once per week due to the COVID-19 pandemic.
[b]On May 24, 2011 over 140,000 black flies were collected in the New Germany, Carver County trap.

Simulium tuberosum *Simulium tuberosum* adults have become a pest of humans in the south Minneapolis area in recent years. *Simulium tuberosum* larvae and adults have occasionally been collected in very low numbers in both larval and adult monitoring samples going back to the start of the black fly program in 1984, but they were never found at pest levels. Larvae of *S. tuberosum* were only found in low numbers in small streams, most commonly in Carver, Scott, and Dakota counties. However, in recent years large numbers of *S. tuberosum* larvae have been found in Minnehaha and Nile Mile creeks. *Simulium tuberosum* is known to feed mainly on mammals, including humans, but its importance as a pest of humans has not been well documented. *Simulium tuberosum* adults were identified in both the net sweep samples and CO_2 samples in 2020. They comprised 7.6% of the of the total black flies in the net sweep samples and 0.14% of the CO_2 samples.

Simulium tuberosum was first suspected of becoming a pest to humans in the District in 2018 when it was implicated as the cause of complaints of biting black flies in neighborhoods near the Minnehaha Creek in areas of South Minneapolis and Edina (Figure 5.3). Large populations of *S. tuberosum* larvae were subsequently found in Minnehaha and Nine Mile creeks. The number of customer complaints fell in 2019 and no outbreaks of *S. tuberosum* were reported, although larvae were found in Minnehaha and Nine Mile creeks that were sampled as part of the monitoring program. In 2020, *S. tuberosum* was again identified as the cause of numerous complaints about biting black flies, mainly in Hennepin County (Figure 5.3). Numerous adults were collected in sweep net samples taken as part of the follow-up investigations into the complaints. Large larval populations were also found in Minnehaha, Nine Mile, and Plymouth creeks. There were also several print and video news stories from local media outlets on the outbreak.

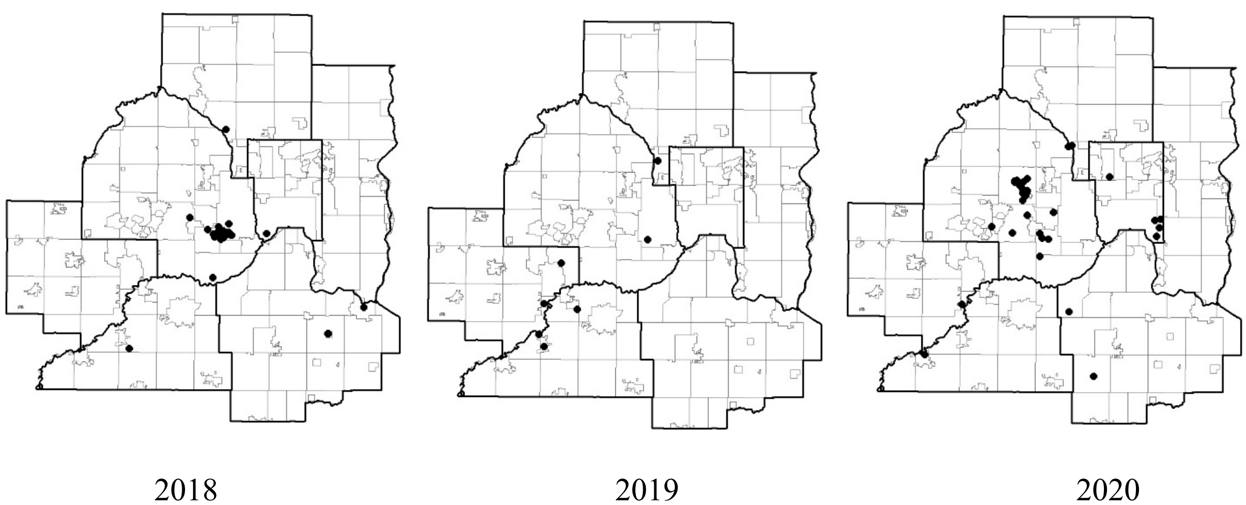


Figure 5.3 Black fly (biting gnats) annoyance customer call locations, 2018, 2019, and 2020.

The District will continue to monitor larval and adult populations of *S. tuberosum* in various areas in 2021. The plan is to focus on larval and adult surveys of *S. tuberosum*. The goal will be to understand the seasonal bionomics and ecology of *S. tuberosum* in the region in an effort to develop of an effective larval control plan with *Bti*. The District has discussed the *S. tuberosum* situation with the MNDNR along with possible control options.

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 2020. 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 5.4. The areas in dark gray and black represent the highest numbers collected, ranging from 250 to more than 500 per trap. High number of black flies were observed in early June in parts of Carver, Scott, and Dakota counties (Figure 5.4). The peak average number of black flies occurred on June 9, slightly above the 13-year average (Figure 5.5). The average number of black flies fell below the 13-year average for the remainder of the season.

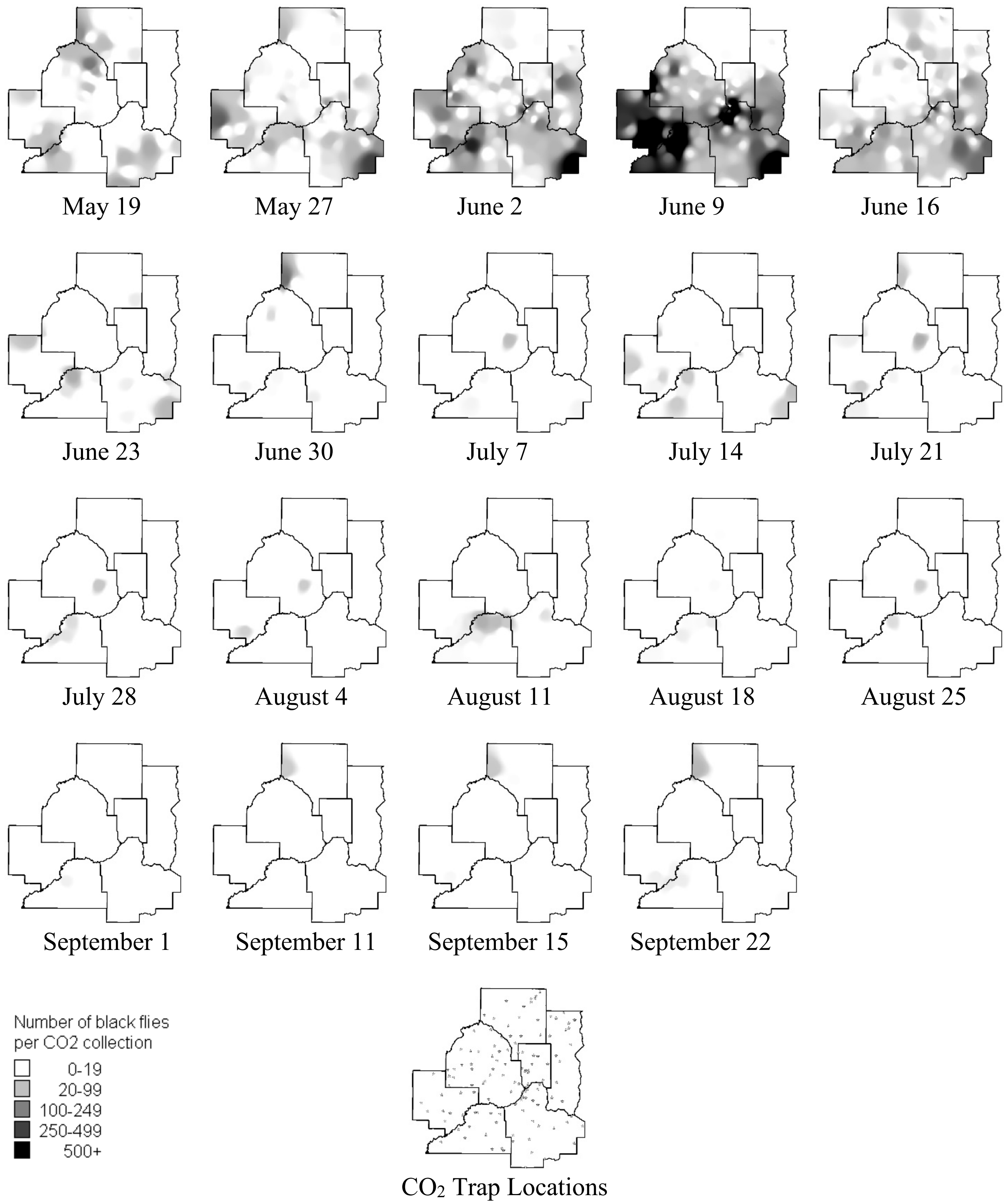


Figure 5.4 Number of black flies collected in mosquito surveillance District low (5 ft) and elevated (25 ft) CO_2 traps, 2020. The number of traps operated per night varied from 123-131. Inverse distance weighting was the algorithm used for shading of maps.

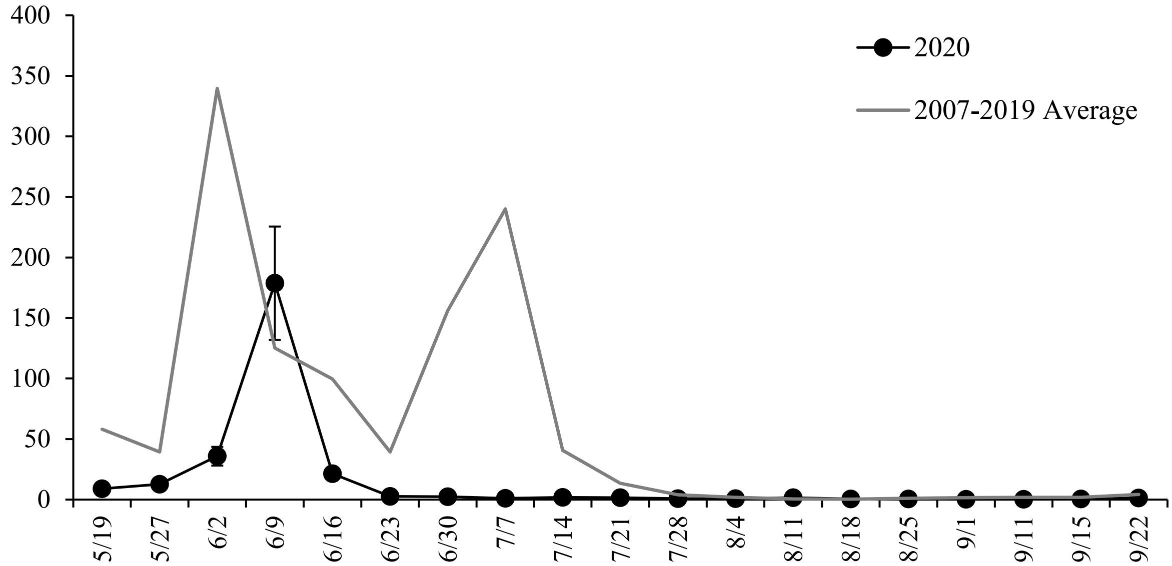


Figure 5.5 Average number of black flies per Monday Night Network CO_2 trap, 2020 vs. 13-year average (2007-2019). Error bars equal $\pm$ 1 standard error of the mean.

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 compiled from the twelve separate years that monitoring samples were collected biennially between 1995 and 2017 indicate that no large-scale changes have occurred in the macroinvertebrate community in the *Bti*-treated reaches of the Mississippi River. Non-target monitoring samples were collected as scheduled in 2019. Sample processing is on schedule for completion during spring 2021 with the report scheduled for summer 2021.

The results of a study to compare the macroinvertebrate community collected on standard 14-plate Hester Dendy multiplate samplers used for the monitoring program to the community collected on 7-plate Hester Dendy samplers was completed. The results showed that there are no significant differences in the macroinvertebrate community collected on the two sampler types. Seven-plate samplers require less time to process and therefore are more cost-effective for the District to deploy in its non-target monitoring program. The MNDNR approved use of 7-plate samplers for future non-target macroinvertebrate community monitoring on the Mississippi River.

2021 Plans – Black Fly Program

2021 will be the 37th year of black fly control in the District. The primary goal in 2021 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. The 2021 black fly control permit application will be submitted to the MNDNR in February. Processing of the Hester-Dendy multiplate samples collected in 2019 for the non-target invertebrate monitoring program on the Mississippi River will be completed and a report submitted to the MNDNR. The Mississippi River non-target monitoring samples will be collected using 7-plate multiplate samplers as scheduled. Studies will be done to gain more knowledge on the distribution, abundance, and ecology of immature and adult *S. tuberosum*. These data will be used to develop an effective larval treatment program if one is deemed necessary. Program development will continue to emphasize improvements in effectiveness, surveillance, and efficiency.

Chapter 6 Product & Equipment Tests

2020 Highlights

- 5-lb/acre dosages of VectoBac® G *Bti* achieved good control of *Aedes vexans* in air sites
- Natular® G30 (5-lb/acre) effectively controlled *Ae. vexans* in ground sites
- Altosid® P35 (3-lb/acre) effectively controlled *Coquillettidia perturbans* in ground sites verifying 2019 results
- VectoLex® FG (20 g/cb) effectively controlled mosquito larvae in catch basins verifying 2019 results

2021 Plans

- Consider emergence cage tests of ground sites treated with VectoLex® FG or Altosid® P35 using a drone to verify effective control of *Cq. perturbans*
- Consider more tests of VectoLex® FG in catch basins to determine a minimum effective dosage and develop an operationally efficient treatment process
- 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.

2020 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 conducted certification testing of one larvicide. 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 2020 were all within acceptable limits (Table 6.1).

Table 6.1 AI content of Altosid® (methoprene) briquets, pellets, and sand; MetaLarv® S-PT granules (methoprene); and Natular® G30 granules (spinosad), 2020.

Product evaluated	No. samples analyzed	AI content: Label claim	AI content: Analysis average	SE
Altosid® XR-briquets	10	2.10%	2.17%	0.0060
Altosid® pellets	10	4.25%	4.67%	0.0234
MetaLarv® S-PT granules	10	4.25%	4.28%	0.0443
Natular® G30 granules	10	2.50%	2.45%	0.0643

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 2020, 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 2020. Aerial *Bti* treatments to control the spring *Aedes* brood began on May 6, four days later than in 2019 and four days earlier than in 2018. All applications used the 5 lb/acre rate to conserve funds because of an anticipated levy shortfall due to COVID-19. In 2020, aerial *Bti* treatments averaged 88.0% control (Table 6.2), comparable to 85.9% control in 2019, 88.0% control in 2018, 84.5% control in 2017, 86.0% control in 2016, 83.7% control in 2015, and 90.4% control in 2014. Percent mortality was calculated by comparing pre- and post-treatment dip counts.

Table 6.2 Efficacy of aerial VectoBac® G applications (5 lb/acre) during the 2020 mosquito season (n = number of sites dipped).

Time period	Dosage rate	n	Mean mortality	±SE*
May 6 – Sept 2	5 lb/acre	367	88.0%	4.6%

*SE= standard error

Natular® G30 and *Aedes vexans* Natular® G30 is used as a summer floodwater (*Ae. vexans*) prehatch. In summer 2018, the efficacy of Natular® G30 was evaluated in depth to explain why more larvae were found in Natular® G30-treated sites than expected. Clarke Mosquito Control (the producer of Natular® G30) worked with MMCD to determine if Natular® G30 was effectively controlling *Ae. vexans* larvae. We discovered that we needed to wait three days after rain flooded a site previously treated with Natular® G30 to give the product enough time to control larvae. Control was comparable to control achieved by *Bti* (VectoBac® G) (see 2018 Operational Review and Plans for 2019 for details).

In 2020, we sampled Natular® G30-treated sites to compare with annual *Bti* efficacy evaluations. The number of sites from which post-treatment samples were collected in 2020 was lower than in 2019 because we had fewer seasonal employees due to the COVID-19 pandemic. Almost identical proportions of sites treated with Natular® G30 and VectoBac® G contained below or above threshold larval abundances when post-dipped suggesting comparable control (Table 6.3), the same result as observed in 2019. The degree of control achieved in VectoBac® G sites was very good and similar to efficacy achieved in previous years (Tables 6.2 and 6.3). Similar control values cannot be calculated for Natular® G30-treated sites, because these sites are not dipped before treatment or before subsequent rain (no pre-treatment dip data available).

Table 6.3 Efficacy of Natular® G30 and VectoBac® G applications during the 2020 mosquito season (n = number of sites dipped).

Material	Dosage rate	n	% below threshold	% above threshold	Mean mortality	±SE*
Natular® G30	5 lb/acre	19	84.2%	15.8%	--**	--**
VectoBac® G	5 lb/acre	367	86.4%	13.6%	88.0%	4.6%

*SE= standard error ** No corresponding pre-dips available for Natular® G30-treated sites

New Control Material Evaluations

The District, as part of its Continuous Quality Improvement philosophy, strives to continually improve its control methods. Testing in 2020 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. The reduced number of seasonal employees hired because of the COVID-19 pandemic limited the amount of research testing that could be completed in 2020.

Larval Control

Altosid® P35 and *Coquillettidia perturbans* In 2019, Central Life Sciences added Altosid® P35, a spherical granule of uniform size, to its Altosid® family of mosquito larvicides that contain methoprene. Helicopter calibration tests demonstrated Altosid® P35 could be applied uniformly using a 3 lb/acre dosage. Due to its non-uniform size and non-spherical shape, Altosid® pellets must be applied using a 4 lb/acre dosage to achieve uniform treatments. The same amount of Altosid® P35 could be used to treat 33% more acreage than by using Altosid® pellets. A 3 lb/acre dosage of Altosid® P35 contains the same amount of methoprene as a 3 lb/acre dosage of MetaLarv® S-PT which has achieved excellent control of cattail mosquitoes. Altosid® P35 and MetaLarv® S-PT are similar in shape and size.

To evaluate effectiveness of Altosid® P35, we treated ten cattail sites with 3 lb/acre of Altosid® P35 on June 2 and 3, 2020. On June 15, 2020, we placed five emergence cages into each of the sites treated with Altosid® P35 and in each of five nearby untreated sites. All adult mosquitoes in each emergence cage were collected twice each week beginning on June 19 through August 4, 2020. This test was a repeat of a similar test conducted in 2019 that suggested that Altosid® P35 at 3 lb/acre effectively controlled *Cq. perturbans*. In 2019, emergence cages were placed three days after treatment. Control appeared to be achieved beginning about 10 days after treatment (see 2019 Operational Review and Plans for 2020 for details). In the 2020 test, we placed emergence cages 8-9 days after treatment.

An average of 0.76 adult *Cq. perturbans* emerged per cage in sites treated with Altosid® P35 between June 15 and August 4. During the same period, an average of 22.68 adult *Cq. perturbans* emerged per cage in untreated sites (Figure 6.1). This difference equates to 96.6% control. Emergence in untreated sites was distributed more typically with a peak in late June while emergence in treated sites was low throughout the sampling period (Figure 6.1). Operational treatments with methoprene formulations typically are completed in late May or very early June (except for frozen sites treated in March), the same as when the sites in this test were treated with Altosid® P35. These results indicate that operational doses of Altosid® P35 effectively control *Cq. perturbans*.

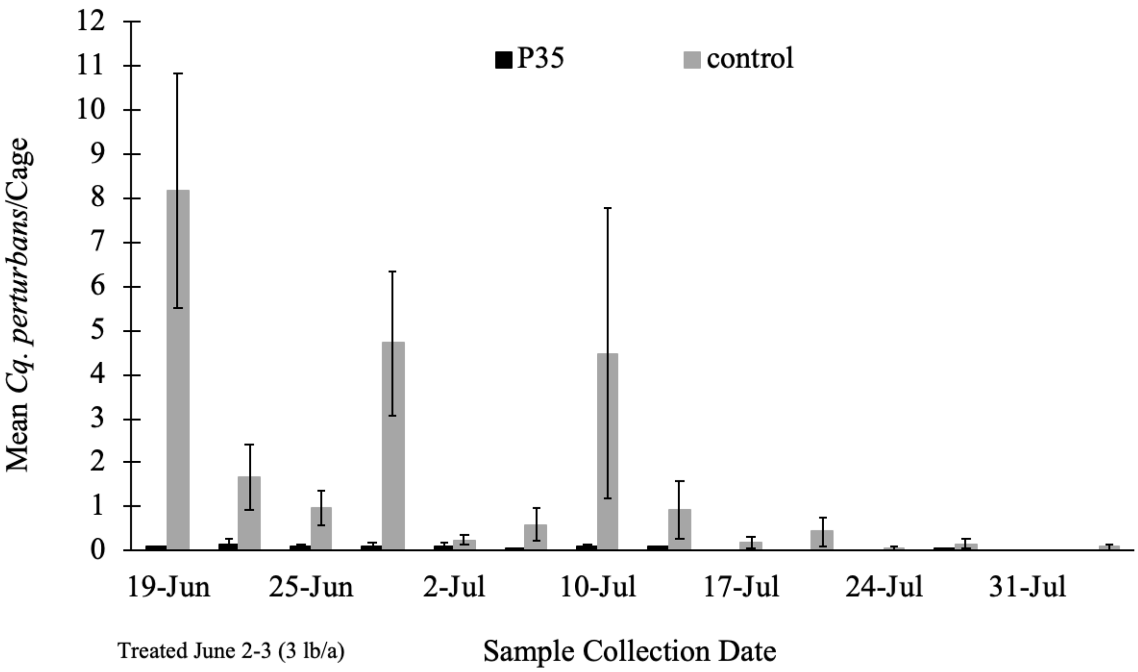


Figure 6.1 Mean emergence of *Cq. perturbans* per sample period in cages in rooted and floating sites treated with Altosid® P35 and untreated (control) sites. Emergence cages were placed on June 15 and sampling occurred from June 15 – August 4, 2020. Treatments occurred on June 2 and June 3 (3 lb/acre). Error bars equal ± 1 standard error of the mean.

Adult *Cq. perturbans* emerged from significantly fewer cages in sites treated with Altosid® P35 than in untreated sites during the entire sampling period (Table 6.4). These results also suggest that Altosid® P35 successfully controlled *Cq. perturbans*.

Table 6.4 Number of emergence cages in untreated sites and sites treated with Altosid® P35 from which adult *Cq. perturbans* emerged during the entire sampling period and after the first eleven days of the sampling period (June 15-August 4).

Treatment	Total cages	Cages with emergence	Cages without emergence	% Cages with emergence	Fisher Exact P-value
Untreated	25	19	6	76%	
Altosid® P35	50	15	35	30%	0.00016

VectoLex® FG in Catch Basins Operationally, we treat catch basins three or four times each season with Altosid® pellets or Altosid® P35 (both 3.5 g per catch basin) to control vector mosquitoes. In 2019 we tested Altosid® P35, Altosid® pellets, and VectoLex® FG in catch basins to verify that we could use all three products to effectively control vectors. Results indicated that all three products effectively controlled vectors for up to four weeks (see 2019 Operational Review and Plans for 2020 for details). We again tested VectoLex® FG at a dosage (20 g per catch basin) to verify good results observed in 2019. We considered including a lower VectoLex® FG dosage (15 g per catch basin) in 2020 to determine if this lower dosage could achieve the desired duration and degree of control but did not because of staff limitations due to the COVID-19 pandemic.

Two groups of catch basins were designated. All catch basins were in St. Paul. Sixty catch basins were treated with VectoLex® FG (20 g per catch basin) on June 15, July 15, August 11, and September 8. Thirty untreated catch basins were monitored in the same manner as treated catch basins. Catch basins from each treatment group were inspected each week by MMCD staff, weather and workload permitting, from the week of larvicide application through September until the temperature dropped enough to inhibit oviposition by mosquitoes in catch basins. We collected and counted larvae and pupae from all catch basins.

The number of larvae (Figure 6.3) and pupae (Figure 6.4) collected from catch basins (untreated or treated with VectoLex® FG) each week varied during the sampling period. Overall, catch basins treated with VectoLex® FG contained fewer larvae and pupae than untreated catch basins (Table 6.5), although one might question the effectiveness of VectoLex® FG because larvae and pupae still are present on many sampling dates (Figure 6.3, 6.4). The lower abundance of pupae in catch basins treated with VectoLex® FG suggested effective control (Table 6.5).

Table 6.5 Mean number of larvae (all instars) and pupae from untreated (control) and VectoLex® FG-treated catch basins (20 g per catch basin) all dates pooled.

		Larvae per dip		Pupae per dip	
Material	No. inspections	Mean	SE*	Mean	SE*
VectoLex® FG	1,053	6.14	1.37	0.06	0.02
Control	523	29.49	6.24	2.89	1.07

*SE= standard error

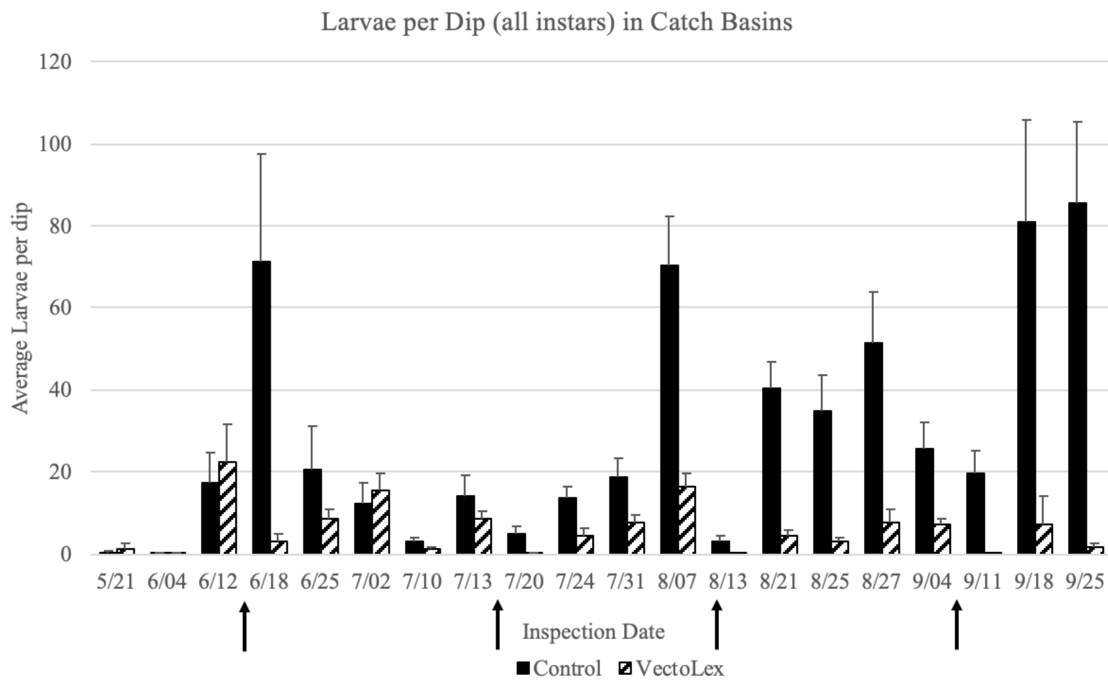


Figure 6.3 Mean number of larvae (all instars) from untreated (control) and VectoLex® FG-treated catch basins (20 g per catch basin) on each sample date. Error bars equal one Standard Error. Arrows indicate VectoLex® FG treatment dates.

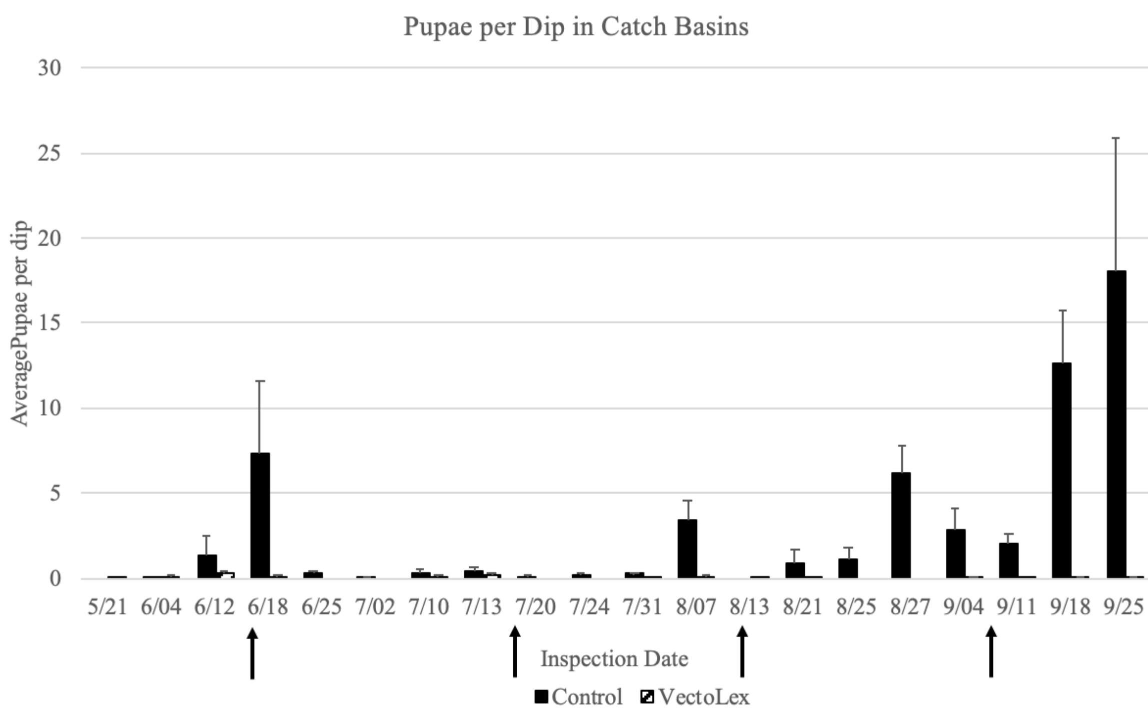


Figure 6.4 Mean number of pupae from untreated (control) and VectoLex® FG-treated catch basins (20 g per catch basin) on each sample date. Error bars equal one Standard Error. Arrows indicate VectoLex® FG treatment dates.

We also evaluated efficacy using the pass/fail strategy outlined by Harbison et al. (2019). The pass/fail evaluation for direct kill larvicides designates a fail as the presence of one or more late instar larvae (instar 3 or 4) or pupae in a catch basin sample (Harbison et al. 2019). Harbison et al. (2019) recommend retreatment if at least 25% of the catch basins are scored as a fail. Based upon this evaluation method, VectoLex® FG very effectively controlled vector mosquitoes developing in catch basins. Only during three of 17 weeks of sampling did VectoLex® FG-treated catch basins include over 25% scoring fail (Table 6.6, Figure 6.5). In contrast, over 25% of untreated catch basins scored fail during 16 of 17 weeks of sampling (Table 6.6, Figure 6.5).

Table 6.6 Percent of catch basins scored as fail from untreated (control) and VectoLex® FG-treated catch basins (20 g per catch basin) (after 6/15 treatment)

	% CBs fail/week		Number of weeks fail	
Material	Mean	(SE*)	<25% CBs Fail	≥25% CBs Fail
VectoLex® FG	13.5%	(2.7%)	14	3
Untreated Control	68.3%	(6.6%)	1	16

*SE= standard error

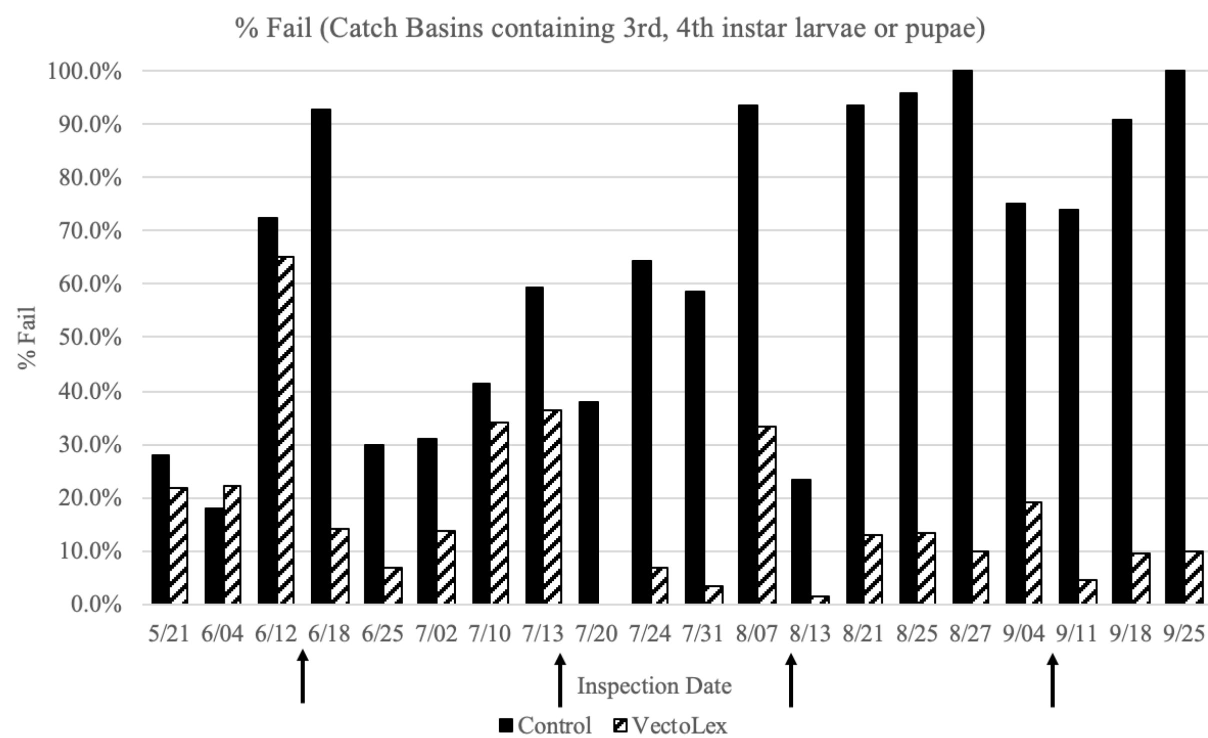


Figure 6.5 Percent of catch basins scored as fail (catch basins containing 3rd or 4th instar larvae or pupae) from untreated (control) and VectoLex® FG-treated catch basins (20 g per catch basin) each sample date.

Next is the question of how long VectoLex® FG at 20 g per catch basin effectively controls mosquitoes in catch basins. We first explored the possibility that rain could be affecting control.

No pattern in the proportion of catch basins scoring fail and rain events equal to or greater than one inch over 24 hours is apparent (Figure 6.6).

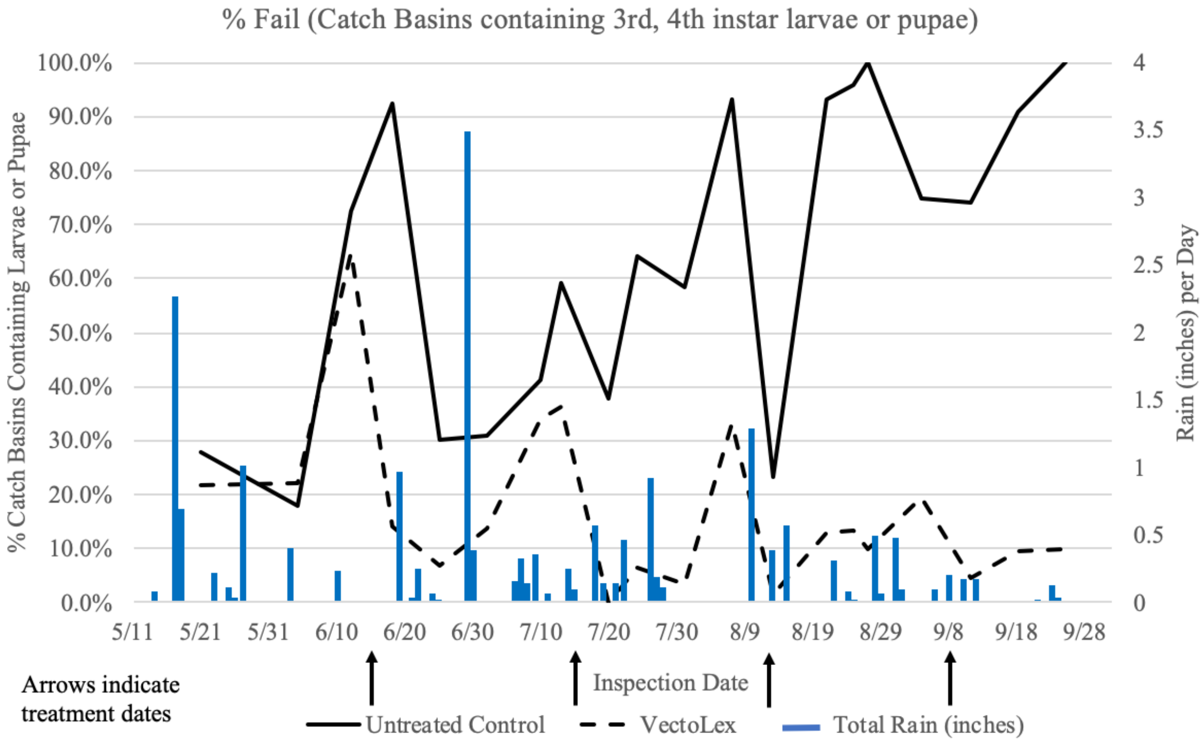


Figure 6.6 Percent of catch basins scored as fail (catch basins containing 3rd or 4th instar larvae or pupae) from untreated (control) and VectoLex® FG-treated catch basins (20 g per catch basin) each sample date including 24-hour total rainfall events.

We used linear least squares regression to evaluate possible impacts of significant flushing rain events (equal to or greater than one inch over 24 hours). Two such rainfall events occurred during the 17-week sampling period (June 29 and August 10) after the first VectoLex® treatment on 6/15. The percent of catch basins scored as fail on each sampling date (dependent variable) was compared to the number of days after the most recent significant rain event that the samples was collected (independent variable). Percent fail values were arcsin-transformed for this analysis.

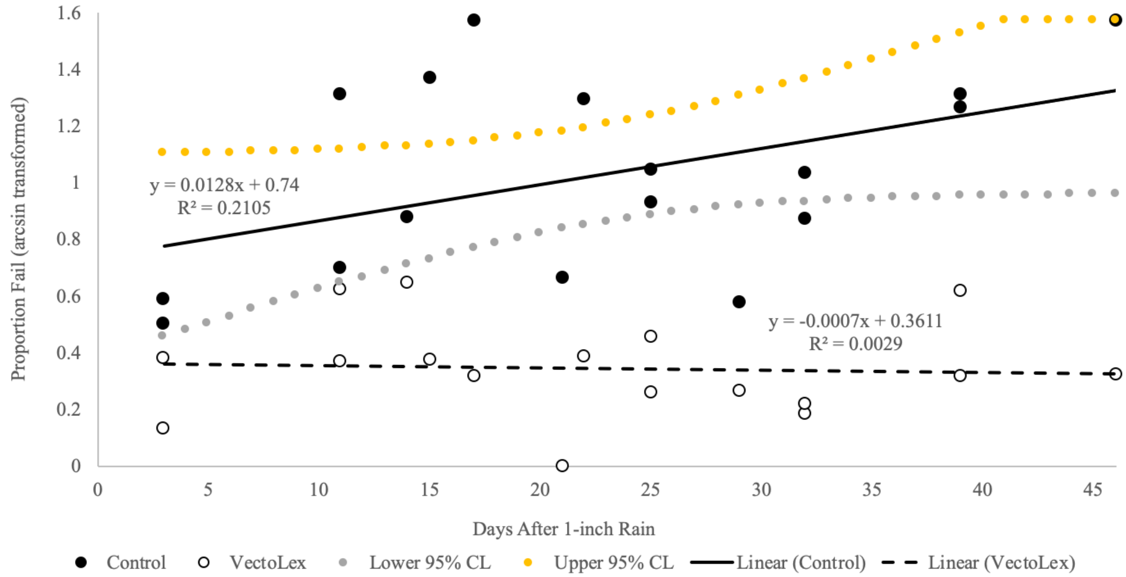
Table 6.7 Least squares regression of percent fail (arcsin-transformed) and days after significant rainfall in VectoLex® FG-treated catch basins (20 g per catch basin) and untreated catch basins separately.

Material	Slope (b)	SD* (of slope)	T**	df***	p-value
VectoLex® FG	-0.0007	0.00356	-0.208	15	0.383
Control	0.0128	0.00639	1.999	15	0.059

*SD = standard deviation; **T = (slope – 0)/SD; ***df = n-2 (n = 17 weeks)

The percent of untreated catch basins that scored fail seemed to increase significantly as time after a significant rainfall increased (the p-value was very close to significant). No significant association was observed in catch basins treated with VectoLex® FG (20 g per catch basin) (Table 6.7, Figure 6.7).

Proportion Fail (Catch Basins containing 3rd, 4th instar larvae or pupae) Versus Days After Rain (1+ inch) (arcsin transformed)



% Fail (Catch Basins containing 3rd, 4th instar larvae or pupae) Versus Days After Rain (1+inch)

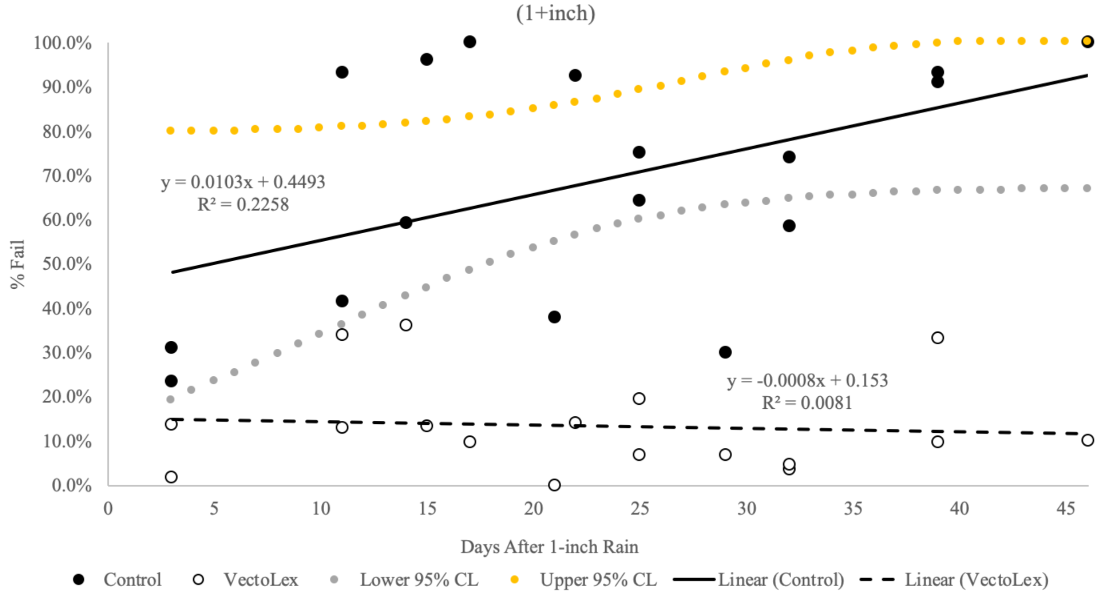


Figure 6.7 Least squares regression lines of percent fail (upper: arcsin-transformed, lower: back-transformed) and days after significant rainfall in VectoLex® FG-treated catch basins (20 g per catch basin) and untreated catch basins separately including 95% confidence limits around the regression line for the untreated control.

These results suggest that populations of larvae and pupae in untreated catch basins increase as more time passes after a significant flushing rain fall event. Control exerted by VectoLex® FG apparently was sufficient during the time-period observed to prevent this increase.

To evaluate the apparent degree and duration of control achieved by VectoLex® FG we used linear least squares regression. The percent of catch basins scored as fail on each sampling date (dependent variable) was compared to the number of days after the most recent treatment (independent variable). Untreated catch basins were scored (days after treatment) by using the most recent VectoLex® FG treatment date. Percent fail values were arcsin-transformed for this analysis.

The percent of catch basins treated with VectoLex® FG (20 g per catch basin) that scored fail increased significantly as time after treatment increased. No significant association was observed in untreated catch basins (Table 6.8, Figure 6.8).

We estimated the duration of effective control (fewer than 25% of catch basins scoring fail) for VectoLex® FG-treated catch basins by using the regression line to predict the amount of time after treatment when the percent of catch basins scoring fail became equal to 25%. We used the 95% confidence limits (back transformed) for the regression line to estimate lower and upper limits of duration of control. The regression line predicts that 25% of the VectoLex® FG-treated catch basins will score fail 24.3 days after treatment (95% confidence limits: 19 – 28 days after treatment). Because there was no significant change in untreated catch basins that score fail relative to the number of days after the most recent VectoLex® FG treatment date (Table 6.8), the expected percent fail value for untreated catch basins was 68.3%, the overall average (Table 6.6).

The percentage of VectoLex® FG-treated catch basins scoring fail remained below 25% for three to four weeks after treatment. This is much lower than the average 68.3% failure rate observe in untreated catch basins. Thus, VectoLex® FG (20 g per catch basin) achieved the desired four weeks of effective control in catch basins.

Table 6.8 Least squares regression of percent fail (arcsin-transformed) and days after treatment with VectoLex® FG (20 g per catch basin); treated and untreated catch basins analyzed separately.

Material	Slope (b)	SD* (of slope)	T**	df***	p-value
VectoLex® FG	0.0168	0.00334	5.037	15	0.0001
Control	0.0046	0.01102	0.416	15	0.3578

*SD= standard deviation; **T = (slope – 0)/SD; ***df = n-2 (n = 17 weeks)

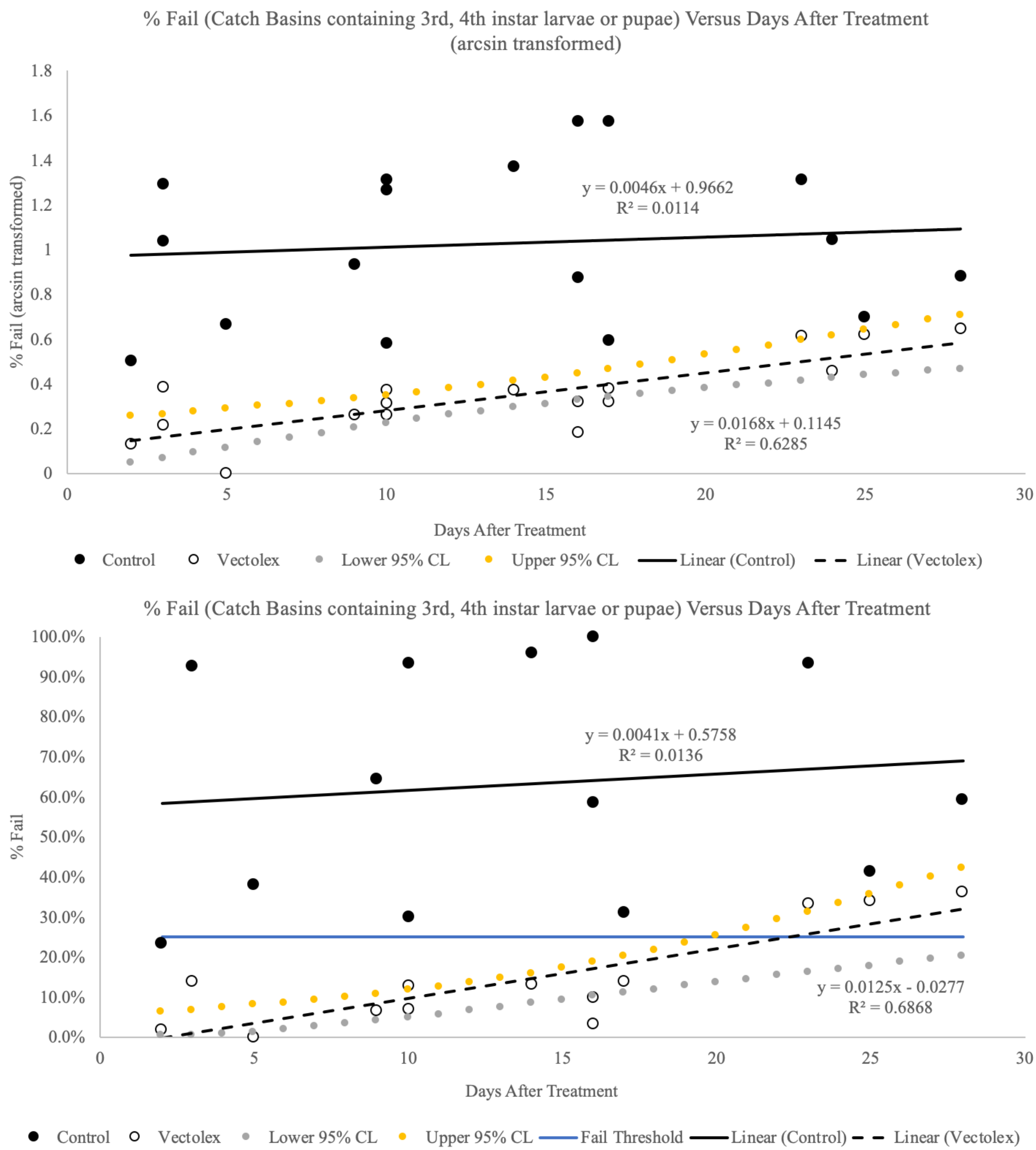


Figure 6.8 Least squares regression lines of percent fail (upper: arcsin-transformed, lower: back-transformed) and days after treatment with VectoLex® FG (20 g per catch basin) in treated and untreated catch basins separately including 95% confidence limits around the regression line with a significant slope (VectoLex® FG-treated).

Adulticide Tests

We did not complete any tests of adulticides in 2020 because of staff limitations due to the COVID-19 pandemic.

Equipment Evaluations

Helicopter Swath Analysis and Calibration Procedures for Larvicides Technical Services and field staff conducted four aerial calibration sessions for dry, granular materials during the 2020 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 Benson Airport in White Bear Lake, MN. Staff completed swath characterizations for seven different operational and experimental control materials. In total, six Jet Ranger helicopters were calibrated, and each helicopter was configured to apply an average of four different control materials.

Drone Swath Analysis and Calibration Procedures for Larvicides Technical Services aided in aerial calibration sessions for the PrecisionVision 22 aerial treatment drone for dry, granular materials in the same manner as we calibrate the helicopters. Staff completed swath characterizations for two control materials applied in 2020 (Altosid® P35 granules and MetaLarv® S-PT). The PrecisionVision 22 drone we utilized for aerial treatments has a hopper system that can manipulate the swath of the material applied by adjusting the voltage to the hopper. The hopper voltage, combined with the flight speed of the drone, and variously-sized flow restrictors affect the swath characterization for the 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 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 one semi-trailer pickup during the treatment season and staff assisted the contractor with loading 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 532 jugs for this recycling program. The control materials that use plastic 2.5-gallon containers are Anvil® 2-2 (6 jugs), Zenivex® E4 RTU (20 jugs), *Bti* liquid (458 jugs), and Altosid® pellets (48 jugs). A portion of the *Bti* liquid came in bulk totes, which significantly reduced the number of jugs generated in 2020.

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.

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 2020, MMCD produced over 475 empty hardwood pallets used in control material transport. Our warehouse staff worked with our vendors and arranged to return the pallets 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 continuing to work 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 unrecyclable insecticide bags. 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 2020, Clarke shipped all of our Natular® G30 granules (100,800 lb) in 63 totes and reduced our packaging use by 2,520 bags. In 2020, Central Life Sciences shipped Altosid® P35 granules (78,000 lb) in 39 totes and reduced the packaging by 1,950 bags. Valent sent MetaLarv® granules (55,000 lb) in bulk totes and reduced the packaging by 1,375 bags. Valent also sent a portion of VectoBac® 12-AS liquid (2,865 gallons) in bulk totes and reduced the packaging by 1,146 jugs. Staff was able to spend less time dealing with waste, and the District eliminated 6,991 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 2020, Valent BioSciences agreed to take back all of their products' waste packaging. Due to the quantity of *Bti* granules used (676,209 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 waste disposal services and an estimated 25,357 lb was eliminated from the waste stream.

Expired Product Disposal In 2020, MMCD worked with Veolia Environmental Services to properly dispose of various mosquito control products. These products were older, experimental product samples that had chemically broken down. Staff also disposed of old calibration materials which were no longer representative of current products. MMCD removed them from our warehouse and ensured these products were handled in an environmentally safe manner.

Warehouse Improvements During the off-season, MMCD staff continued to reorganize the District Warehouse facilities to increase efficiency and safe operations. MMCD rebuilt the weighing station and installed bulk tanks for our adulticide mixing process. Staff removed obsolete materials and equipment to gain useable warehouse space. Overall, there were many additional revisions completed that will improve warehouse operations and support our safety culture.

References

Harbison, J. E., Nasci, R. S. and Clifton, M. 2019. Operational Quality Control for Catch Basin Larviciding at the North Shore MAD. Wing Beats. 30: 5-13. Summer 2019.

2021 Plans – Product and Equipment Testing

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 our mosquito control equipment.

We will consider emergence cage tests of ground sites treated with VectoLex® FG or Altosid® P35 using a drone to verify effective control of *Cq. perturbans*.

We will consider more tests of VectoLex® FG in catch basins to gather more data about the minimum effective dosage with the goal of developing an operationally efficient method for treating catch basins with VectoLex® FG.

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

Chapter 7 Supporting Work

2020 Highlights

- Received Certificate of Waiver or Authorization from FAA to make larvicide treatments from drones (UAS)
- MMCD staff treated 63 sites, including some that resulted in significant cost savings
- Continued use of drones for aerial photography and site scouting
- Adjusted data systems to support work-from-home and social distancing in the workplace
- Continued to collect catch basin data from cities to update MMCD data
- Created virtual events for public interaction

2021 Plans

- Continue testing drone-based granular treatments and how that process can fit into MMCD operations
- Continue catch basin map improvements and test new ways to record treatments

2020 Projects

Unmanned Aircraft Systems (Drones)

Unmanned aircraft systems (UAS) are used by various mosquito control agencies to investigate difficult-to-access mosquito habitats, capture aerial imagery, and apply insecticides. This technology is rapidly evolving, and rules and regulations are in place to protect the privacy and safety of humans and their property.

The drone workgroup at MMCD is tasked with training staff to operate UAS, test various uses for these platforms, and guide the future directions of drone usage within the District. Currently, 11 employees certified as UAS pilots under the FAA's Part 107 regulation which covers commercial uses for drones weighing less than 55 pounds. Six additional employees may also take the test in 2021 to become certified pilots, and three more employees joined the workgroup in 2020. We are currently finalizing a Standard Operating Procedures document as well.

PrecisionVision 22

In 2020, we utilized our three, small quadcopters for scouting and photography purposes. The main use was to photograph sites to update our internal map imagery. This was necessary for areas with outdated imagery and recently constructed areas that altered the landscape by either eliminating or creating new mosquito breeding sites. We had at least 9 certified pilots complete 22 flights updating aerial imagery as needed. Drones can be useful to investigate treacherous wetland habitats (e.g., floating cattail mats) and large (100+ acre) wetlands that would require additional staff to search for access points and suitable areas to survey mosquito larvae.

In 2020, we tested the operation, ease-of-use, and effectiveness of granular applications (Figs. 7.1 and 7.2) in some small (~3 acres) wetland habitats in the District. These small sites are too large for ground treatments and approach the minimum size that helicopters can comfortably treat. In order to use a treatment UAS in Minnesota, our pilots need to have their aerial applicators license from MDA as well as FAA authorization. We submitted and received a COA (Certificate of Waiver or Authorization) from the FAA which grants us the ability to apply control materials from our treatment drone. Additionally, our UAS are registered with both the FAA and MnDOT. The treatment drone was calibrated for both Altosid® P35 and VectoLex® using the trampoline system we use for calibrating helicopter treatments. We treated 29 sites (39.5 acres) with 592.45 lb of VectoLex®, replacing at least 13,000 briquets. We also treated 34 sites (48.19 acres) with 127.72 lb of Altosid® P35. A trailer was purchased and extensively modified to house and transport the treatment drone.

We anticipate drones will facilitate cost savings for the District by increasing efficiency of larval inspections (from up-to-date maps, identifying access points, and decreasing staff time in cumbersome sites) and replacing costly briquet treatments with cheaper granular applications at troublesome cattail sites. Also, we believe that using drones to treat difficult and dangerous sites has significant safety advantages. In 2021, we will continue utilizing drones to update our aerial imagery and to scout sites as needed. We will also continue testing under which scenarios treatments by drone are most advantageous; this includes continuing to replace briquet sites and seeing how helpful drone treatments are for pre-hatch control. In addition, we will recalibrate the treatment drone for materials already tested and for other granular materials. We are planning to test the efficiency of drone treatments by directly comparing the time it takes to treat by drone versus traditional methods as well as gathering data on the uniformity of these treatments.

Figure 7.1 Treatment using PrecisionVision 22 UAS.

Figure 7.2 Adjusting the voltage to the treatment hopper.

Unfortunately, we had an accident with the treatment drone which required repairing the rotors, a GPS receiver, and the outer shell. The accident occurred because of a loss of link between the controller and the drone which resulted in emergency procedures being implemented (i.e. 'return-to-home' was initiated). However, the drone did not ascend to an appropriate height and landed in a tree on its return to home. The crew acted swiftly to recover the drone and we learned how to respond and avoid accidents in the future, how to report incidents to the FAA, and the range for the treatment drone controller.

Data Systems & Mapping

The year 2020 marked some significant changes in data systems:

- Work-from-home options in response to COVID-19 were quickly enabled by IT staff in March and continue as needed for many workers
- When seasonal staff returned in the spring, training materials were made available through our enterprise data system "Webster", so they could access information on their MMCD phone rather than in-person presentations
- The entire Webster interface and database were moved to a new cloud-based server and parts of the underlying software updated by Houston Engineering Inc; this should provide room for growth and improve maintenance while controlling costs
- Drone treatment recording forms were added, which include the required information for an aerial treatment (but differ from our helicopter recording process)
- New Jersey light trap entry was added, another step in getting all adult collection data available through a common platform; we also added a larval sample recording error notification tool to help maintain data quality
- Improvements were made in Mobile Maps, part of the Webster field interface that lets users look up information on sites and get driving directions

In mapping, we are changing our desktop Geographic Information System (GIS) from MapInfo to the open-source GIS program QGIS. This gives us a well-supported powerful GIS that works well with the cloud database environment that supports Webster. However, it has required us to learn a new system and develop new procedures. This transition to QGIS is a major focus of many staff over the winter 2020-2021 season.

We are continuing our catch basin map updates and have collected catch basin location data from 26 cities and are using that to update our records (288,000 catch basins) (Fig. 7.3). City data unique identifiers are retained to make future data exchanges easier. In 2021, we are working on new ways to manage catch basin treatment data and plan to begin testing tablets for data entry.

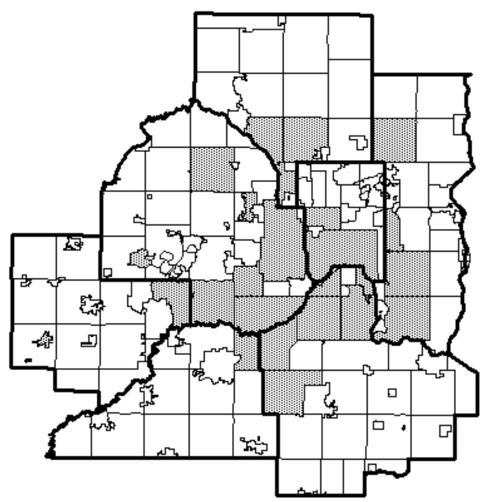


Figure 7.3 Cities with updated catch basin map data.

Public Web Map MMCD's public access map on https://mmcd.org/ continues to let people see wetland inspection and treatment activity on our 82,205 sites in real time and access history back to 2006. Inspection and treatment information is updated automatically from our “Webster” internal data system. The map is accessed through the main MMCD web site. Web stats showed 2,408 access clicks, suggesting similar use rates as calls to the front desk.

GIS Community MMCD staff participate in the MetroGIS collaborative, and we benefit from work by many other units of government. In 2020, we contributed towards the Metropolitan Council’s regional air photo acquisition done for the census. That photoset, served online by MnGeo, the state Geospatial Information Office, was a valuable addition when updating wetland maps in the fall. We use aerial photos collected by metro-area counties as they become available. MMCD also uses basemap and geocoder services from the Metropolitan Council. We share our wetland data through MnGeo’s Geospatial Commons.

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.

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

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 1993-2020. 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 2020, the DD_{40F} total went over 200 in week 18 (ending May 2), relatively late compared to most dates in the last 20 years. Aerial treatments for spring *Aedes* (gray boxes) began the week following and were completed within two weeks (ending May 16).

Aerial treatments are not started until a sufficient number of sites are over threshold, seasonal inspectors are hired, and helicopters have been calibrated. In 2020, the aerial treatment start date was somewhat delayed while field staff were working out COVID-19 protocols for worker safety. It was helpful that the spring temperatures stayed low and delayed larval development.

- 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	2019	2020	Last date in week (2020)
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	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	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	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	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	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	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	0	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	0	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	0	0	
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	0	4	
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	0	16	
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	2	17	Mar 21
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	19	34	Mar 28
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	33	59	Apr 4
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	67	106	Apr 11
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	125	116	Apr 18
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	**222**	184	Apr 25
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	278	**316**	May 2
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**	352	393	May 9
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	483	483	May 16
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	583	631	May 23
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	748	823	May 30
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	974	845	Jun 6
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	1156	1262	Jun 13

262 Average CumDD40 Aerial Treatment Start (1993-2020)
(we started treatments as early as 5 days prior to "Last date in week")

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

Evaluating and Reducing 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 at https://mmcd.org/non-target-impact-studies/.

Pollinators and Mosquito Control The status of pollinator populations (e.g., honeybees, native bees, butterflies, flies, etc.) is a matter of concern, and MMCD continued efforts to minimize negative effects on pollinators. Our biological control materials for mosquito larvae pose no risk to bees. The pyrethroids we use as fog or vegetation spray to control adult mosquitoes have label restrictions that protect pollinators and when used correctly are relatively low risk for bees. Staff are trained to recognize areas where pollinators may be active so they can adjust operations to minimize exposure.

MMCD consulted with the U.S. Fish and Wildlife Service in 2018 about the degree of risk of MMCD's mosquito control operations might pose to the rusty patched bumble bee (*Bombus affinis*), an endangered species listed in 2017. Based on the bee's biology and the timing, location, and materials MMCD uses, the overall risk of MMCD's operations to the bee was very low (see report at https://www.mmcd.org/docs/publications/RustyPatchedBumblebeeReview.pdf. We continue to update our information about the bee and its habitats as that becomes available.

In September of 2020, Public Affairs Coordinator Alex Carlson and Executive Director Stephen Manweiler conducted a phone discussion with an editorial assistant from the Monarch Joint Venture (MJV) to discuss MMCD operations in relation to monarch protection. This discussion led to the Monarch Joint Venture revising the F.A.Q. on the MJV website in relation to mosquito control. MMCD also made connection with the MJV Education Coordinator and scheduled a webinar for their group in July 2021.

In March of 2020, Public Affairs Coordinator Alex Carlson spoke to the Minnesota Hobby Beekeepers Association along with the Fieldwatch/Driftwatch coordinator with the Minnesota Department of Agriculture (MDA) to talk about efforts to protect honeybees along with native pollinators like the rusty patch bumblebee and the monarch butterfly. Beekeepers register hives through "BeeCheck" and we train our staff to check for those hives on DriftWatch (https://mn.driftwatch.org/map). MMCD staff also watch for hive locations when doing field work and modify adulticide treatments as needed.

Several members of MMCD assisted with the revisions of the Category L Manual for pesticide applicators with the MDA and University of Minnesota Extension in 2020 which included updated guidelines for protecting pollinators. Additional trainings were provided at the Category L recertification clinic hosted by MMCD in July and subsequent recertification clinics hosted by Extension in September and October.

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 https://www.pca.state.mn.us/water/pesticide-npdes-permit-program. The checklist for mosquito control permits is given at https://www.pca.state.mn.us/sites/default/files/wq-wwprm9-05b.pdf.

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 five 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 website.

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".

As a vector of West Nile virus (WNV), the primary target species for larval surveillance on the MVNWR is *Culex tarsalis*. Surveillance for *Cx. tarsalis* adults indicated their population near the refuge remained low in 2020, and MMCD made no requests to conduct larval surveillance in the wetlands of the refuge. Adult mosquito surveillance from CO_2-baited light traps near the refuge (Fig. 7.5) indicated that the initial emergence of the *Aedes vexans* population was later than typical, with the species first appearing in most of the Minnesota River Valley area traps on June 2. *Aedes vexans* collections peaked during the week of July 14 in traps near MVNWR at 545 per trap and exceeded 440 per trap two other times (June 9, August 25). For traps near MVNWR, collections of *Ae. vexans* were greatest within one mile of the refuge.

Collections of *Cx. pipiens* and *Cx. restuans* were relatively low at locations near MVNWR in 2020, with only location H291 (Fig. 7.5) showing one night above threshold. *Culex pipiens* and *Cx. restuans* serve as the enzootic or maintenance vectors 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 were historically low in traps near MVNWR in 2020 with only 34 specimens collected during the entire season. This pattern was consistent throughout most of MMCD's service area in 2020.

Mosquitoes collected from traps near MVNWR were tested for WNV from the beginning of June through the end of September. There were no WNV positive samples from the area in 2020.

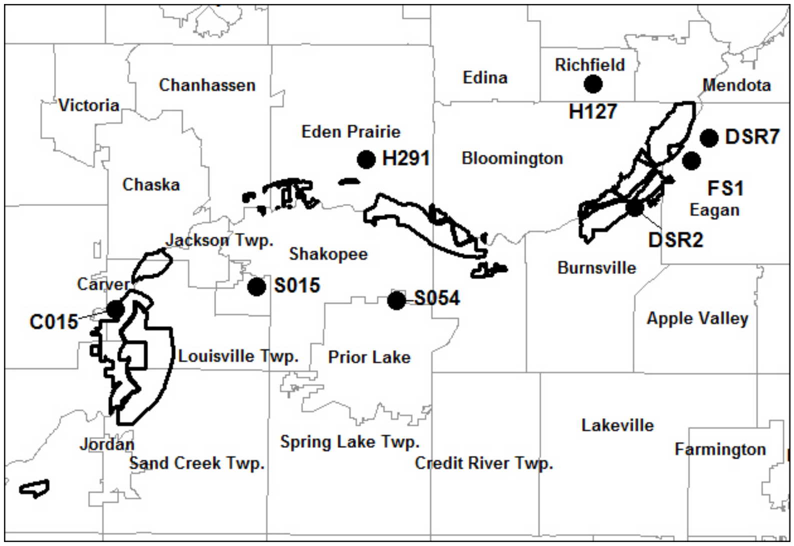


Figure 7.5 CO_2 trap locations (circles) near the Minnesota Valley National Wildlife Refuge. Solid, dark lines delineate refuge boundaries.

Public Communication

Notification of Control The District continues to post daily adulticide information on its website 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 (helicopter activity) are also posted on the website and posted on Twitter, Facebook, and Instagram. E-mail notice is also available through Granicus.

Calls Requesting Service The most frequent type of call from the public continues to be requests for larval or adult mosquito treatment. In 2020, the number of these calls peaked the week of July 13, which coincides with the peak of mosquitoes collected in sweeps (Figure 7.6). Calls declined quickly at the end of July and remained low throughout most of the rest of the season, thanks in part to less rain and lower mosquito counts.

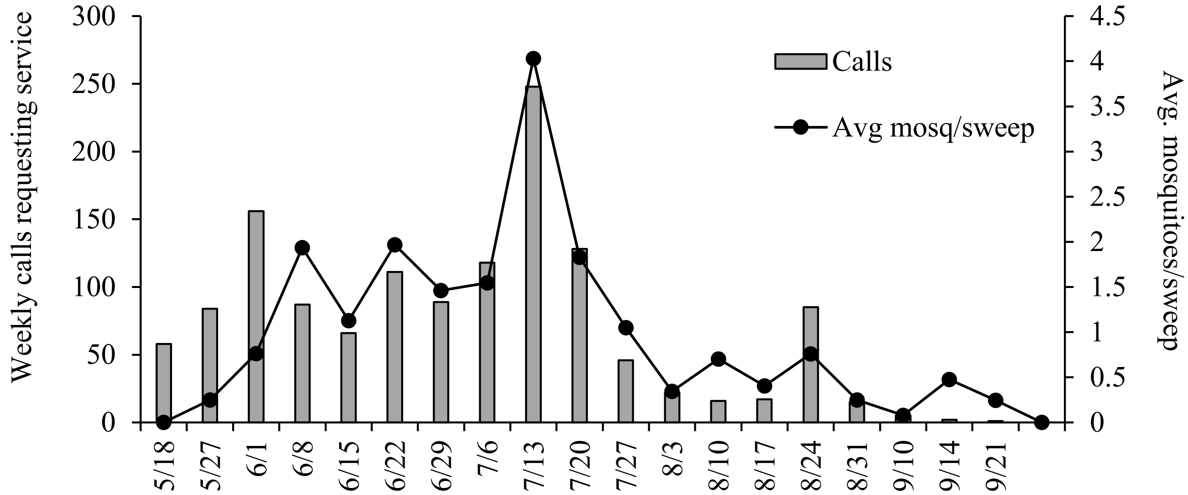


Figure 7.6 Calls requesting service and sweep net counts, by week, 2020.

Requests specifically asking for adult mosquito treatment or to check breeding sites in 2020 were down significantly compared to recent years (Table 7.1). Part of the decline was likely due to less rain and lower mosquito numbers during the second half of the season. There were almost no requests for treatment at public events, because Department of Health guidelines due to the COVID-19 pandemic led to the cancellation of most public events. Requests for tires to be picked up and requests for limited or no treatment remained about the same as in previous years.

Table 7.1 Yearly citizen call totals (including e-mails) by service request type, 2010-2020.

	Number of calls by year										
Service request type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Check a larval site	164	626	539	609	1,068	447	886	1,151	601	802	438
Request adult treatment	1,384	1,291	1,413	1,825	2,454	1,633	2,499	1,157	1,212	1,144	1,030
Public event, request treatment	78	67	61	70	93	91	105	101	91	71	12
Request tire removal	332	315	417	351	429	366	377	363	325	411	411
Request or confirm limited or no treatment	53	56	54	[a]136	[b]146	139	158	126	75	69	76

[a] Historic restriction “calls” moved into new system
[b] Beehive locations added into call system to track restrictions

Community and School Presentations Due to the COVID-19 pandemic, MMCD did not participate in any in-person school presentations and very few community presentations in 2020. To make up for this lack of interaction with the public, we created and released a series of entertaining and educational videos that we published on our website and social media channels.

Video stills from "Field Day with Field Operations Supervisor", "Mosquito Bite Games", and "Cool Science with an Entomologist"

To provide a resource for teachers, we created an 18-minute video that covers mosquito biology, habitat, and other facts to help K-12 students become better informed citizens. The video was released on our YouTube page as "Unlisted" so only those who are given the link can access it. As of January 1, it was viewed 305 times and many teachers have sent positive feedback.

Public Events In 2020, public events were essentially non-existent. We did participate in the Minnesota State Fair online marketplace, and our East facility created a mosquito scarecrow for a walk-through event in the City of Vadnais Heights. We are hopeful that 2021 will see the return of county fairs and city festivals!

Social Media As part of an ongoing effort to notify residents when and where treatment is to take place and to offer another point of contact for the District, MMCD has maintained a presence on Facebook, Twitter, and Instagram. MMCD currently has 759 Twitter followers, up from 536 followers at the end of 2019, 1,540 "Total Page Likes" on Facebook, up from 1,123 in 2019, and 218 followers on Instagram up from 78 at the end of 2019.

MMCD currently uses the service Granicus (formerly GovDelivery) to give advance notification to District residents of adult mosquito treatments. Granicus is also used to distribute press releases and make announcements about job openings. 2020 ended with 7,242 individual subscribers who opted in to receiving some sort of communications from MMCD, which is up from 6,108 at the end of 2019.

Sustainability Initiative

MMCD's Sustainability Initiative began in 2013 and examines the economic, environmental, and social impacts of adopting sustainable practices throughout District operations. It is now a standing team with workgroups as listed below. Some special activities were curtailed in 2020 because of COVID-19 response, but most processes developed in previous years were carried forward.

Reducing Energy Usage For electricity, we are continuing the transition to LED lights and are seeing significant energy and cost savings. We are looking into our vehicle fleet options for fuel savings.

Reducing Waste We continue our pesticide container recycling and reuse program in cooperation with the manufacturers. Composting is widely used for items such as food scraps and paper towels.

Renewable Energy Six of our seven offices are signed up to receive electricity from solar gardens through Xcel and US Solar 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 and promote the health of our staff. We started 2020 with an employee gathering and food drive, and then moved to socially distanced activities and donations.

Sustainability Culture The team is working to make sustainability part of the culture of the District, recognizing that sustainable living and working also is the most efficient way to deliver services to District citizens using available resources. We are starting to plan options for our annual Sustainability Summit for 2021 and continue to promote sustainability in training for returning staff.

Professional Association Support

American Mosquito Control Association MMCD staff members continued to provide support for the national association: Mark Smith is a member of the AMCA Science and Technology Committee and represents the North Central Mosquito Control Association at the AMCA regional associations' presidents meeting.

Midwest Center of Excellence for Vector-borne Disease The MCE-VBD brings together academic and public health expertise from Illinois, Iowa, Michigan, Minnesota, and Wisconsin. Scott Larson and Kirk Johnson collaborate with the MCE-VCD as experts in tick-borne and mosquito-borne disease, respectively. Collaborations have led to the identification of Jamestown Canyon virus (JCV) in adult mosquito samples collected in Anoka County and northeast Washington County. Larval *Ae. provocans* collections from Wisconsin have shown that the virus can be transmitted from adult mosquitoes to their progeny (transovarial transmission). The ultimate goal is to identify which species vector JCV to humans. Investigating potential insecticide resistance is also a goal for the MCE-VBD with colleagues across the region conducting bioassay tests for resistance. Also, weekly conference calls with regional partners allow for the dissemination of trends in vector populations and for relaying results of research.

North American Black Fly Association John Walz served as President and Program Chair for this association again in 2020, and Carey LaMere maintains the association's website, https://nabfa-blackfly.org/ and produces the meeting program. NABFA is not planning a meeting for 2021 due to COVID-19.

North Central Mosquito Control Association Mark Smith and Scott Larson served on the Board of Directors of this regional association for Minnesota, North Dakota, South Dakota, Wisconsin, Iowa, and the central provinces of Canada. The 2020 annual meeting was cancelled due to COVID, but plans are underway for a 2021 virtual meeting. The meeting qualifies attendees for pesticide applicator re-certification for MN and ND. Visit their website to learn more at http://north-central-mosquito.org/WPSite/.

Scientific Presentations, Posters, and Publications

MMCD staff attend a variety of scientific meetings throughout the year and publish scientific studies. Following is a list of publications released and papers and posters presented during 2020 and talks that are planned in 2021.

Publications

2020 Presentations & Posters

Carlson, A. 2020. Tools and tips for educating the public about mosquito control before an emergency happens. Presentation: Michigan Mosquito Control Association Annual Meeting in Lansing, MI.

Grant S. 2020. Drone use at the Metropolitan Mosquito Control District. Presentation: North American Black Fly Association Meeting in Mobile, AL.

Manweiler, S. 2020. Cattail mosquito control program in Minnesota. Presentation: Michigan Mosquito Control Association Annual Meeting in Lansing, MI.

Manweiler, S. 2020. Mosquito control and the Endangered Species Act. Presentation: Department Seminar, University of Minnesota Entomology Department, St. Paul, MN.

Walz, J. 2020. MMCD Black Fly Control Program update. Presentation: North American Black Fly Association Meeting in Mobile, AL.

2021 Presentations & Posters

Beadle, K. 2021. Drone surveillance of artificial larval habitats. American Mosquito Control Association Annual Meeting (virtual).

Smith, M. 2021. Strategic use of pre-hatch larvicides can optimize your mosquito control operations. American Mosquito Control Association Annual Meeting (virtual).

Appendices

APPENDIX A Mosquito and Black Fly Biology and Species List

Mosquito Biology

There are 51 species of mosquitoes in Minnesota. Forty-five species occur within the District. Species can be grouped according to their habits and habitat preferences. For example, the District uses the following categories when describing the various species: disease vectors, spring snow melt species (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 et al. 2015), 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 CO_2 traps and New Jersey light traps.

Other *Culex* Three additional species of *Culex* (*Cx. pipiens, Cx. restuans,* and *Cx. salinarius*) are vectors of WNV. All three species use permanent and semi-permanent sites for larval habitat, and *Cx. pipiens* and *Cx. restuans* use storm sewers, containers, 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 collect *Cx. pipiens* and *Cx. restuans* for WNV testing.

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 *Ps. 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 nets.

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 tree hole and 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, adults emerge and ride 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. The following biologic information for specific black fly species is based on Adler et al. (2004).

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.

Simulium tuberosum develops in a wide range of flowing waters from small streams to the large rivers. In the District, it has been found primarily in small stream samples but can occur in large river samples as well. It is assumed multivoltine and females are presumably mammalophilic.

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 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*	uncommon/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-summer	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*	rare, spring	37.		*territans*	common
14.		*implicatus*	uncommon, spring	371.	*Cx*. unidentifiable		
15.		*intrudens*	rare, spring	372.	*Cx.*	*pipiens/restuans*	when inseparable
16.		*nigromaculis*	uncommon, summer				
17.		*pionips*	rare, spring, northern MN spp.	38.	*Culiseta*	*inornata*	common
18.		*punctor*	common, spring	39.		*melanura*	uncommon, EEE
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* (adult samples only)			501.	Unidentifiable mosquito		
263.	Non-*vexans Aedes* (larval airwork)			601.	Non-mosquito insect (ex. phantom midge)		
264.	Summer *Aedes* (adult samples only)						

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

Genus Abbreviations for Mosquitoes

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

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

Code	Genus	species	Significance/Occurrence/Treated or non-treated
Black Flies			
91.	*Simulium*	*luggeri*	common, summer, treated
92.		*meridionale*	common, summer, treated
93.		*johannseni*	common, spring, treated
94.		*vittatum* spp group	common, spring/summer, non-treated
95.		*venustum* spp group	common, spring, treated
96.	Other Simuliidae		can use to speed small stream ids, used pre-2019 for codes 98-112
97.	Unidentifiable	Simuliidae (family level)	too small to id, or damaged
98.	*Simulium*	*annulus*	rare, spring, non-treated
99.		'aureum' spp group	rare, spring/summer, non-treated
100.		*croxtoni*	rare, spring, non-treated
101.		*excisum*	rare, spring, non-treated
102.		*decorum*	uncommon, spring/summer, non-treated
103.		*rugglesi*	uncommon, spring/summer, non-treated
104.		*silvestre*	rare, spring, non-treated
105.		*tuberosum* spp group	common, spring/summer, non-treated
106.		*verecundum* spp group	rare spring/summer, non-treated
107.	*Cnephia*	*dacotensis*	common, spring, non-treated
108.		*ornithophilia*	rare, spring, non-treated
109.	*Ectemnia*	*invenusta*	rare, spring, non-treated
110.	*Heledon*	*gibsoni*	uncommon, spring, non-treated
111.	*Prosimulium*	unidentifiable	rare, spring, non-treated
112.	*Stegoptera*	*mutata/emergens*	uncommon, spring, non-treated

APPENDIX B Average Number of Common Mosquitoes Collected per Night in Four Long-term NJ Light Trap Locations and Average May to September Rainfall, 1965-2020. 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
2019	0.02	0.03	0.03	0.19	5.86	0.02	0.89	8.27	26.67
2020	0.09	0.05	0.12	0.21	10.52	0.01	3.88	16.49	20.00

*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 2020

The following is an explanation of the control materials currently used by MMCD. The specific names of products used in 2020 are given. The generic products will not change in 2021, 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 — Central Life Sciences
Altosid® P35 — EPA# 89459-95

Altosid® P35 consist of methoprene formulated in spherical granule. Altosid® P35 is 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 3-5 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.

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

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. 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).

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 2020 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
Altosid® P35	Methoprene	4.25	2.5 lb	0.1063	30
			3 lb	0.1276	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
VectoBac® G	*Bti*	0.20	5 lb	0.0100	1
			8 lb	0.0160	1
VectoLex® FG	*Bs*	7.50	8 lb	0.6000	7-28
			15 lb	1.1250	7-28
			0.044 lb* (20 g)	0.0034*	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
Zenivex® E4 [c]	Etofenprox	4.00	1.0 fl oz	0.0023	<1
Anvil® [d]	Sumithrin	2.00	3.0 fl oz	0.0035	<1
Pyrocide® [e]	Pyrethrins	2.50	1.5 fl oz	0.00217	<1
Merus™ [f]**	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] 0.30 lb AI per 128 fl oz (1 gal)
[d] 0.15 lb AI per 128 fl oz (1 gal)
[e] 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)
[f] 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, 2012-2020.The actual geographic area treated is smaller because some sites are treated more than once**

Control Material	2012	2013	2014	2015	2016	2017	2018	2019	2020
Larvicides									
Altosid® XR Briquet 150-day	165	189	193	186	168	166	167	162	180
Altosid® XRG	23,436	6,948	52	0	0	0	0	0	0
Altosid® Pellets 30-day	13,172	15,813	26,179	31,494	19,173	17,939	10,202	12,020	729
Altosid® Pellets catch basins (count)	226,934	246,300	239,829	248,599	240,806	252,694	262,851	265,915	264,399
Altosid® P35 30-day	0	0	0	0	0	0	0	0	26,784
Altosid® P35 Catch basins (count)	0	0	0	0	0	0	0	0	11,648
MetaLarv™ S-PT	2,750	14,063	18,073	21,126	33,409	23,740	23,574	23,003	18,408
Natular® G30	9,524	15,000	14,950	8,840	13,023	12,271	15,662	17,277	8,946
Altosid® XR Briquet catch basins (count)	458	375	437	450	448	445	509	476	470
VectoLex® FG granules	0	2,330	3,064	3,777	6,076	4,773	4,660	5,036	1,858
VectoBac® G *Bti* corn cob granules	207,827	150,280	255,916	258,148	234,120	136,173	134,926	156,089	139,006
VectoBac® 12 AS *Bti* liquid (gal used) Black fly control	3,097	3,878	4,349	4,351	3,112	3,621	3,234	4,362	4,085
Adulticides									
Permethrin 57% OS Permethrin	8,578	9,020	8,887	6,093	8,128	5,038	3,771	3,367	1,742
Scourge® 4+12 Resmethrin/PBO	8,078	37,204	44,890	19,767	23,072	2,090	0	0	0
Anvil® 2 + 2 Sumithrin/PBO	27,486	36,000	31,381	27,183	16,399	11,683	7,790	3,665	584
Pyrocide® Adulticide	0	0	5,338	3,605	0	0	0	0	0
Zenivex® Etofenprox	0	0	0	10,380	34,984	23,097	26,918	15,289	4,124

APPENDIX F Graphs of Larvicide, Adulticide, and ULV Fog Treatment Acres, 1984-2020

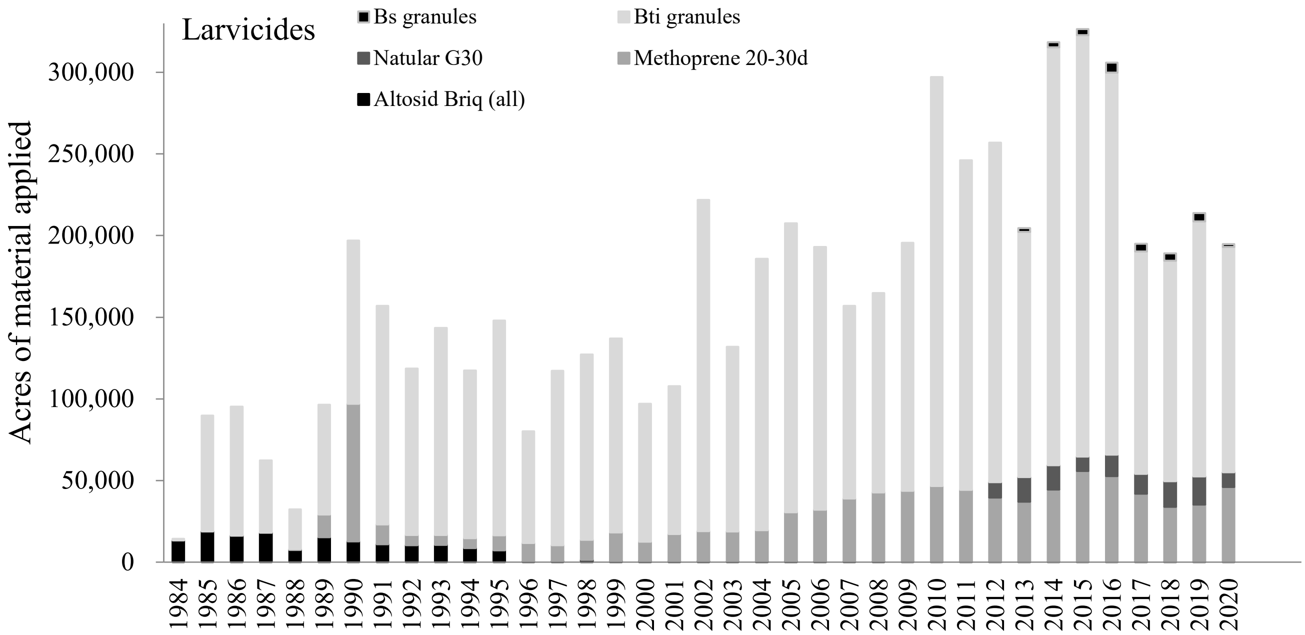


Figure F.1 Summary of total acres of larvicide treatments applied per year since 1984. For materials that are applied to the same site more than once per year, actual geographic acreage treated is less than that shown.

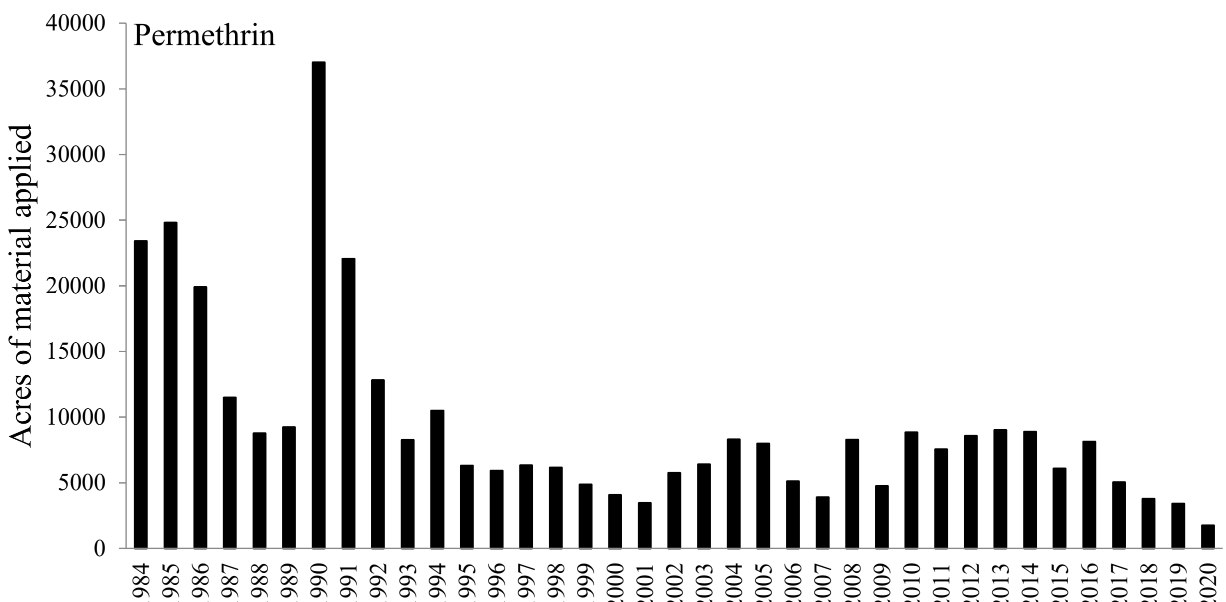


Figure F.2 Summary of total acres of permethrin treatments applied per year since 1984. This material may be applied to the same site more than once per year, so actual geographic acreage treated is less than that shown.

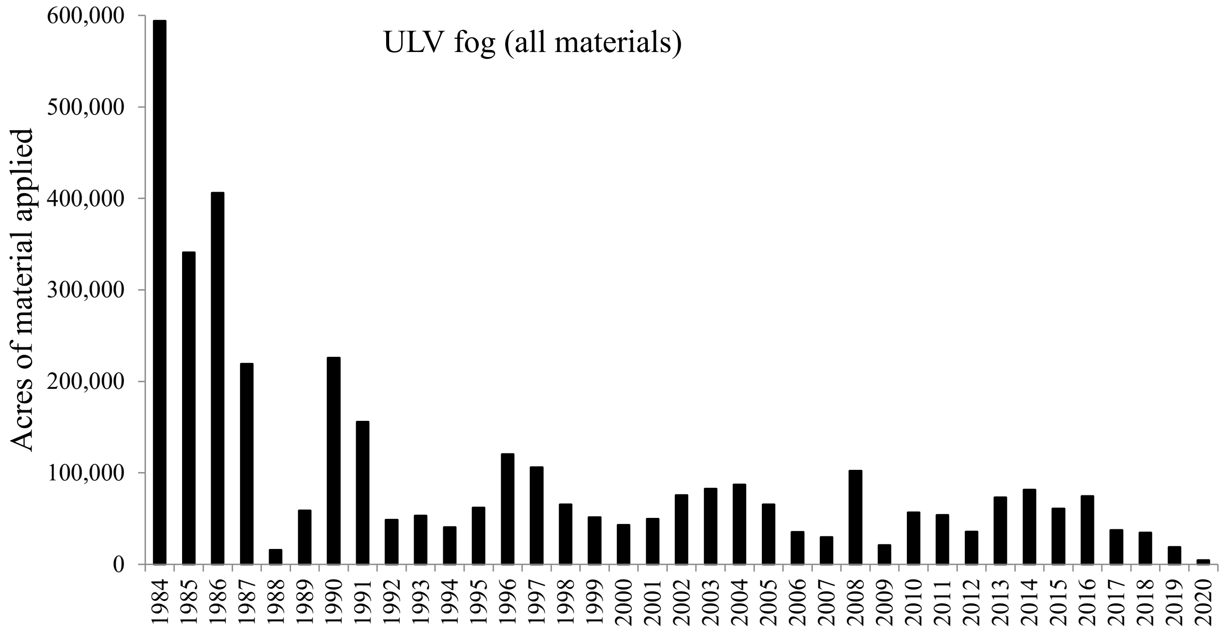


Figure F.3 Summary of total acres of ULV fog treatments applied per year since 1984. This material may be applied to the same site more than once per year, so actual geographic acreage treated is less than that shown.

APPENDIX G Control Material Labels

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

Altosid® Pellets (EPA# 2724-448)

Altosid® P35 (EPA# 89459-95)

MetaLarv® S-PT (EPA# 73049-475)

VectoBac® 12AS (EPA# 73049-38)

VectoBac® G (EPA# 73049-10)

VectoLex® FG (EPA# 73049-20)

Natular® G (EPA# 8329-80)

Natular® G30 (EPA# 8329-83)

Permethrin 57% OS (EPA# 8329-44)

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 11, 2021

TAB Members Present:
Christine Wicks, MN Dept. of Agriculture
John Moriarty, Three Rivers Park District
Phil Monson, MN Pollution Control Agency
Gary Montz, MN Dept. of Natural Resources
Elizabeth Schiffman, MN Department of Health
Robert Sherman, Independent Statistician
Vicky Sherry, US Fish and Wildlife Service
Chris Smith, MN Department of Transportation
Steve Kells, University of Minnesota
Susan Palchick, Hennepin County Public Health
Don Baumgartner, US EPA

MMCD Staff in Attendance: Stephen Manweiler, Nancy Read, Diann Crane, Scott Larson, Janet Jarnefeld, Kirk Johnson, Carey LaMere, Alex Carlson, Mark Smith, John Walz, Paul Youngstrom

Guests: Ken Simmons, Entomologist, advisor to Black Fly Program

(Initials in the notes below designate discussion participants)

Welcome and Call to Order
Chair Steve Kells called the meeting to order (in virtual meeting room) at 12:30 p.m., welcomed everyone to the meeting, and asked all present to introduce themselves. Steve then called on MMCD staff for their presentations.

Overview and Background
Stephen Manweiler presented background on budget, adaptations to the program to deal with COVID-19 pandemic risks, and employee changes. We had hoped to increase control in 2020 but concerns about pandemic-related income reductions led to a more conservative approach. We had over 60 incidents where people had potentially been exposed and took precautions. Three people tested positive, and there was no transmission at work. We shifted some material use strategies because Bti requires use of N95 masks, and those were in limited supply (we also donated some to health care workers). As it turned out the income collection was not as reduced as we feared, and with a drier year there was less need for control, so we ended the year in a good position, and are ready for 2021, and hope to restore some services. We expect to maintain pandemic-related safety measures in 2021, including a somewhat reduced summer staff to maintain 1 employee per vehicle.

Chair asked that questions be held to after the next presentation for the sake of time.

2020 Season Overview
Diann Crane described the categories of mosquitoes found in the District. She outlined temperature and precipitation pattern for 2020, including early warmth, an April snowfall, five major rains and a dry fall. Adult mosquito numbers had some significant peaks but were much higher in the outer untreated areas ("Priority 2" zone).

GM – population prediction for *Cq. perturbans*, graph 1.14, looks like when cattail numbers are low the model was good, but when there are higher numbers, it is not so good. What are you doing with the model? Is it used for driving control in the next year? DMC – model was initiated by Sandy Brogren, former entomologist, and developed by Roger Moon, developed to test the theory that the fall rainfall predicted the next year's cattail mosquito numbers. SL – it explains about 60% of the variation, which is not bad for a very simple model. SM – for control program, it gives us an idea of whether we should plan for higher or lower amounts, but most planning is based on actual sampling. SK – model could be useful to evaluate whether there are other factors such as expanding habitat that are affecting the population.

Mosquito-borne Disease
Kirk Johnson presented an update on mosquito-borne disease in the District. It was a quiet year for mosquito-borne disease, which was welcome in a pandemic year. No La Crosse encephalitis (LAC) cases in MMCD or MN in 2020, and it was the fourth consecutive year without an MMCD LAC case. Jamestown Canyon virus (JCV) has been around for many years but is considered an emerging disease as human JCV cases in both MN and WI have been dramatically increasing. While there were higher case numbers the last four years, it was not seen much in 2020. There was one human JCV case in 2020 and one JCV positive mosquito pool from northern Anoka County. We plan similar adult testing in 2021 and are planning some extra larval surveillance (postponed work from 2020) to understand the biology of these species better to make sure our surveillance and control is targeted well for the species involved. Our testing did not detect any eastern equine encephalitis (EEE) in MMCD. There were also no West Nile virus (WNV) cases in MN and very few nationwide. Kirk compared vector mosquito numbers from our last epidemic in 2018 with 2019 and 2020 numbers, the only difference being that the *Cx pipiens* 2020 late July and early August levels were lower than 2018. He also discussed the low *Cx. tarsalis* numbers in 2020. Kirk described the factors that lead to WNV epidemics and predicted a good year for WNV cases in 2021 due to the anticipated high level of small birds that will have been unexposed to WNV, leading to higher numbers of birds infected with WNV and then available for transmission to and from vector mosquitoes.

CS - Might the low detections of disease be attributed to a lack of testing as people avoided seeking out medical care due to COVID? Do you have testing numbers? (see response from ES later)
CS - Do disease rates in mosquitoes correlate with human infection/disease rates?
KJ – not necessarily, if the samples are from mosquito species that are feeding on birds it may not.

Tick Surveillance
Janet Jarnefeld presented data on the tick program. We were able to maintain the sampling despite COVID. The numbers of *Ixodes scapularis* were somewhat lower than recent peak years,

and the number of positive sites was also less. We did detect some *I. marxi*. We received more lone star tick reports. In 2021 we plan to resume distribution of educational materials. She thanked the Minnesota Department of Health for their dedication and hard work during the pandemic.

ES – thanks, Janet, we all got reassigned to COVID, in reference to earlier question did not have any time to deal with surveillance for human cases of mosquito-borne disease.

Black Fly
John Walz reported on the black fly monitoring and control in 2020. The small stream work in the spring was somewhat reduced because of the COVID delay in seasonal hiring. The large river levels, while somewhat high at times, were manageable (in contrast to flooding in 2019). We have seen an increase in customer calls in recent years. We are also seeing higher numbers of *Simulium tuberosum* which had not originally been included on our permit with the DNR. We have done additional sampling to identify larval habitats for this species and are working with the DNR to develop an addendum for treatments for this species. We continue to do non-target sampling.

There were no questions brought up.

Control Materials – Efficacy Tests
Stephen Manweiler described testing done in 2019-2020 on Altosid P35, a new methoprene formulation that has a more uniform size than the previous pellets that can allow us to use less material to achieve a similar level of control. Emergence cage tests for control of cattail mosquitoes showed good results in 2020 when material was applied on June 2-3, 12 days before sampling. In 2019, there had been some emergence for the first 10 days after treatment, but good control after that. Given the 2020 results, we plan to use Altosid P35 for cattail treatments.

There were no questions.

Kirk Johnson described tests done on VectoLex FG, a controlled release formulation of *Bacillus sphaericus*, which was tested for potential use in catch basins. This is important for us because it has a different active ingredient with a different mode of action than our regular methoprene-based treatments and can help to avoid development of resistant populations. Tests in 2019 had looked promising. Tests in 2020 looked like we were achieving good control, with relatively few larvae surviving to pupal stage. This material has less AI per pound than the methoprene pellets that we use, so treatments require more material, but is still manageable for our bike crews.

SK – will be interesting to see if you can reduce the dose and still maintain efficacy with *B. sphaericus*. KJ – we were surprised to see how well it remained in the catch basin and continued to work after a major rainfall, so the lower dose may work operationally.

Drone Update
Scott Larson described drone usage for mosquito control at MMCD, including scouting for sites, updating aerial photos for mapping, and applying insecticides. We have on-site drone pilot classes for staff and have chosen to require staff to pass the FAA Part 107 test before using any

drone. For doing treatment, a MN Category B Aerial Applicator license is also required. We now have a Certificate of Authorization from the FAA that allows treatment and sets requirements. We did have one incident where a drone collided with a tree and we followed the incident reporting protocol with the FAA. This was the first year we treated any sites by drone. We used the Precision Vision 22 which has a hopper for granular applications. We purchased an enclosed trailer for hauling it and the drone is bolted down in the trailer while on the road. The drone is calibrated in the same way as when we calibrate helicopters, and we can control dose by controlling speed, swath width, and flight path. We treated 34 sites with Altosid P35 (48.19 acres) and another 29 sites (39.5 acres) with VectoLex (15 lb/acre). Even though a two-person minimum is required for drone work, fewer man-hours were required to treat the VectoLex sites with a drone than by treating them by hand with Altosid briquets. We are working on a standard operating procedure document and appreciate guidance on that from staff at a mosquito control agency in Grand Forks, ND. In 2021 we plan to continue to treat small sites and test how drone treatments fit into operations.

JM – at what elevation do you usually fly? SL – about 150 feet. JM – any bird reactions, either frightened or hawks attacking the drone? SL - none seen. CS- at MnDOT our drone was attacked by swallows on a bridge inspection.
SK – as part of SOP do you have an Incident Response Plan for spilled material? NR – we have referred to current plans for other application methods CW – submit IRP to Lucy Hunt in Emergency Response Unit for review. SK – also consider toxicity, quantity of material and where it might land; if the drone goes down in a site, how will you extract, not only the material, but the drone itself, and the batteries. SL – the drone can carry 22 lb of material, but 15 lb works best for not draining the battery.

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

Discussion and Resolutions
Chair Steve Kells opened the floor for discussion and possible resolutions they would like to put forward to communicate with the MMCD Commissioners.

SK noted he works with a lot of commercial and industrial pest management services in urban areas and was impressed by MMCD's COVID response. Not only operations and safety, but our budget planning, as well. He said that compared with other places, MMCD was on the ball and was willing to go the extra mile. Discussion led to the following.

Resolution: The TAB commends the MMCD staff and management on their efforts to maintain operations and budget in consideration of COVID-19 restrictions and needs, without interruption in services.
Motion by PM, second by CS
Motion passed without dissent.

Discussion – CS - Anything we want to discuss about monarch listing decision by USFWS, and possible impact in future? Recently they decided listing the monarch [as endangered species] is warranted but "precluded", might go into effect as soon as 2024. VS – agree that is correct. SM – we have conducted monarch studies in the past, we can use that to start conversation with

USFWS similar to what we did with rusty patched bumble bee. VS - agreed. CS – There was an incident in Fargo this past year. CW – We received the complaint; Fargo was applying an adult mosquito application at the same time monarchs were migrating. Huge numbers killed. We did an investigation and worked on plans to prevent this in the future. There was an investigation write up that Christine can provide to MMCD. SK – was there any sampling of the butterflies? CW – we did not, we were notified too late so the samples were degraded. However, the timing of the butterfly kill was right after the aerial adulticide treatment. SK – wondering, the timing was right, but would like to make sure that if there is an incident there is a way to get killed insects analyzed, have seen other instances where there were other sources involved. NR – We have talked with mosquito control in Fargo, in that instance no one collected samples of the killed species, would be great if we knew how to collect those samples quickly if we needed to. CW – we have protocols, in this case we were not notified. The Fargo case had quite an impact on the public. SK –Fargo has a greater reliance on adulticiding so MMCD already takes steps to prevent this, mostly by doing a lot of larviciding before adulticiding is even considered. Discussion led to the following:

Resolution: The TAB recognizes MMCD's current efforts to minimize nontarget impacts associated with adulticides and recommends that MMCD staff follow USFWS monarch butterfly threatened or endangered species listing discussions and review current research and past incidents to minimize further non-target impacts.
Motion by CS, second by CW.
Motion passed without dissent.

The final discussion led to the following.
Resolution: The TAB supports the program presented in the 2020 Operational Review and 2021 Plan and acknowledges and appreciates the efforts of the MMCD staff on its presentation.
Motion to approve made by PM, Second ES
Motion passed without dissent

There being no further discussion, the TAB adjourned at 3:35 p.m. Motion by ES, Second by BS. Approved by all.

Our Vision

To be the leading mosquito abatement district in the world

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

Our Mission

To promote health and well being by protecting the public from disease and annoyance caused by mosquitoes, black flies, and ticks in an environmentally sensitive manner.

Our Values

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

mmcd
METROPOLITAN MOSQUITO CONTROL DISTRICT

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