METROPOLITAN MOSQUITO CONTROL DISTRICT

2019 OPERATIONAL REVIEW & PLANS FOR 2020

Annual Report to the Technical Advisory Board

Plymouth facility field inspector dipping for cattail mosquitoes

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 2020

Mike Gamache	Anoka County
Mandy Meisner	Anoka County
Robyn West	Anoka County
James Ische	Carver County
Tom Workman	Carver County
Thomas Egan	Dakota County
Mary Liz Holberg	Dakota County
Liz Workman	Dakota County
Jan Callison	Hennepin County
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Jeff Johnson	Hennepin County
Jim McDonough	Ramsey County
Mary Jo McGuire	Ramsey County
Rafael Ortega	Ramsey County
Michael Beard	Scott County
Tom Wolf	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 2019-2020

Gary Montz, Chair	Mn Dept. of Natural Resources
Donald Baumgartner	US EPA
Stephen Kells	University of Minnesota
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	Tech Services/Black Fly
Scott Larson	Assistant Entomologist
Mike McLean	Public Affairs
Nancy Read	Technical Services Coordinator
Mark Smith	Tech. Serv./Control Materials
John Walz	Technical Services/Black Fly

METROPOLITAN MOSQUITO CONTROL DISTRICT

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April 22, 2020

Dear Reader:

The following report is the Metropolitan Mosquito Control District's (MMCD) 2019 Operational Review and Plans for 2020. 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, 2020 are included in this report.

TAB's recommendations and report were accepted by the Commission at their April 22, 2020 meeting. The Commission approved the MMCD 2019 Operational Review and Plans for 2020 and thanked the TAB for their work.

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

Sincerely,

Stephen A. Manweiler
Executive Director

DEPARTMENT OF NATURAL RESOURCES

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

Dear Commissioner Workman:

The Technical Advisory Board (TAB) met on February 11, 2020 to review and discuss MMCD operations in 2019 and plans for 2020. 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 members and MMCD staff, the TAB approved the following resolutions.

1. The TAB supports the program presented in the 2019 Operational Review and 2020 Plan and acknowledges the efforts of the MMCD staff on its presentation.

2. The TAB commends MMCD on your ability to manage budgets and keep focused on the tasks needed, including being prepared for emergencies and emerging issues.

Sincerely,

Gary R Montz

Gary Montz
Chair, Technical Advisory Board
Research Scientist 2, Aquatic Invertebrate Biologist
MN DNR, Division of Ecological and Water Resources

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Executive Summary

The Metropolitan Mosquito Control District (MMCD or the District) strives to provide cost effective service in an environmentally sound manner. This report presents MMCD staff efforts to accomplish that goal during 2019 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 2020 as we continue to provide an integrated mosquito management program for the benefit of metro area citizens.

Mosquito Surveillance

Weather and mosquito production are inextricably linked, and this year there were several significant events that factored into the timing and emergence of mosquito populations. Heavy winter storms and a late 10-inch snowfall from April 10-12 brought the season snowfall total to 76.8 inches, which was 22.7 inches above average. After mid-March, conditions were favorable for a slow snowmelt which was conducive to providing ample spring *Aedes* habitat. Rainfall during the prime mosquito production period of April 29 through September 30 averaged 26.67 inches in the District, which was 6.9 inches above the 60-year average. Precipitation was above normal every month in 2019, except for June.

Adult spring *Aedes* populations peaked June 10, and the summer *Aedes* and *Coquillettidia perturbans* (cattail mosquitoes) both peaked the week of July 15. The *Cq. perturbans* population was higher in 2019 than predicted, and with increased fall and winter precipitation, the predicted numbers for 2020 are higher still. Despite heavy rains in mid-September, there was no major egg hatch that required treatment.

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.

2019 was an uncharacteristically quiet year for West Nile virus throughout the Midwest and particularly in Minnesota. The Minnesota Department of Health reported three cases in the state, two in District residents, which is down from 19 cases in 2018. MMCD tested 649 mosquito pools using the RAMP® method; five were positive for WNV. The first positive pool was collected on August 7, which is later than normal. There were no cases of LAC in Minnesota and four cases of JCV, two in District residents. Eliminating water-holding containers that provide larval habitat for many vector species continues to prove an effective strategy for preventing mosquito-borne illnesses. In 2019, staff collected and recycled 9,763 tires and eliminated 1,611 containers that serve as mosquito oviposition sites.

The District continued monitoring the distribution of ticks in the metro area. Sample processing is underway and preliminary results through September 19, 2019 suggest *I. scapularis* numbers were somewhat lower than last year. Preparations are underway for responding to possible introductions of Asian longhorned ticks into Minnesota.

Mosquito and Black Fly Control

MMCD's program focuses on control of mosquitoes while they are in the larval stage and uses the insect growth regulator methoprene, the bacteria *Bacillus thuringiensis* var. *israelensis* (*Bti*), *B. sphaericus*, and the bacterial product spinosad. MMCD applied larvicide to 213,587 acres, which is 24,396 more acres than in 2018 (189,191 acres treated). A cumulative total of 266,391 catch basin treatments were made in three rounds to control WNV vectors. Adulticide treatment acres in 2019 (22,321 acres) were lower than in 2018 when 38,479 acres were treated.

We have continued expanded larval spring *Aedes* surveillance in Priority Area 2 (P2), the rural area of the District with higher adult abundance. The goal was to potentially shift some spring larvicide treatments into P2 to target suspected vectors of JCV. In 2019, we maintained the P1 spring *Aedes* larval threshold, raised in 2018 from 0.5 to 1.0 larvae per dip, to treat sites that contained higher concentrations of larvae (in both P1 and P2). In 2019, we treated more total acres for spring *Aedes* than in 2018, however, given the increase in P1 acres, we were not able to treat additional P2 acres compared to 2018.

To control black flies in the metro area, MMCD treated 27 small stream sites, and made 41 large river treatments with *Bti* when the larval population of the target species met the treatment threshold. However, the Minnesota River *Bti* treatments were delayed until mid-June due to the dangerous flood-level conditions. The average number of adult black flies per sweep in 2019 was 1.8, which is higher than the 1996-2018 average of 1.27. Black fly specific CO_2 traps collected record numbers of black flies in areas where flooding occurred.

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. Natular® G (5 lb/acre) effectively controlled *Ae. vexans* in air and ground sites. Altosid® P35, a new granular formulation, effectively controlled spring *Aedes* larvae at 2.5 lb/acre and appeared to control *Cq. perturbans* in ground sites at 3 lb/acre. This formulation can allow us to reduce cost and reduce total active ingredient used in aerial treatments, and we plan to use it extensively in 2020.

Data Management, Public Information, Sustainability, and New Technologies

MMCD continued to explore how drones can be incorporated into our program. We purchased a third small quadcopter (DJI Mavic 2 Zoom) in 2019; we are using the drones for scouting and photography to update our internal map imagery. We also began testing drones for granular treatments and purchased a system for planned testing in 2020.

We launched a new official MMCD website in 2019 with improved navigation and better accessibility across devices. Public requests for adult mosquito treatments were down slightly compared to 2018 with the peak coming in early June. MMCD staff made presentations to 2,205 students in 23 schools during the 2019 calendar year.

Sustainability efforts continued to expand and become an integral part of MMCD operations. Electricity use across the District is down 34% in the past six years. Six of our seven offices signed up to receive electricity through solar gardens and three facilities came online in 2019 (Oakdale, Maple Grove, and Plymouth). We also worked with manufacturers to continue to expand the use of reusable bulk totes to hold our materials.

Per TAB recommendation, MMCD consulted with the U.S. Fish and Wildlife Service about the degree of risk of MMCD's mosquito control operations pose to the endangered rusty patched bumble bee (*Bombus affinis*). We were able to conclude that the overall risk is very low, and we released a summary on the MMCD website.

Chapter 1 Mosquito Surveillance

2019 Highlights

- Snowfall season total was 76.8 inches, 22.7 inches above normal
- Winter was categorized as "Severe" with cold temperatures through mid-March
- A slow snowmelt in March was countered by a blizzard from April 10-12
- The first rain event to produce a major summer *Aedes* hatch occurred May 19-25 and the last brood inducing rain event occurred August 25-30
- Despite heavy rains Sept 8-14, mosquito eggs were in diapause and did not hatch
- Identified 18,584 larval and 9,584 adult samples
- Adult spring *Aedes* levels peaked June 10, *Cq. perturbans* peaked the same time as the summer *Aedes*, July 15
- Predicted catch rate for *Cq. perturbans* for 2019 was 57.1/trap. The actual value was 66.1/trap. The prediction for 2020 is 90.2

2020 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 *Cx. 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.

2019 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, the rain gauge data is entered directly into the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) system to make the measurements available more quickly for each other, the National Weather Service (NWS), and the public. This system has limitations because of the sparse gauge network in some areas of the District.

The NWS River Forecast Center (RFC) creates a 4x4 km grid of precipitation estimates based on a combination of NEXRAD (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 through September using historical MMCD rain data and CoCoRaHS gauges. This time period is referred to as the 'mosquito season'. April rainfall can influence adult emergence in May as well. The average rainfall for the weeks of April 29 through September 30, 2019 was 26.67 inches, which is 6.9 inches above the 60-year District average of 19.77 inches.

For the second year running, there was heavy snow in April; almost ten inches fell between April 10-12. Figure 1.1 shows the weekly precipitation averages experienced from April-September 2019. Average weekly rainfall was over one inch many weeks of the season, especially in May. The end of June through mid-July was also very rainy. Three weeks at the end of August saw rainfall in excess of one inch. The highest weekly averages occurred in September.

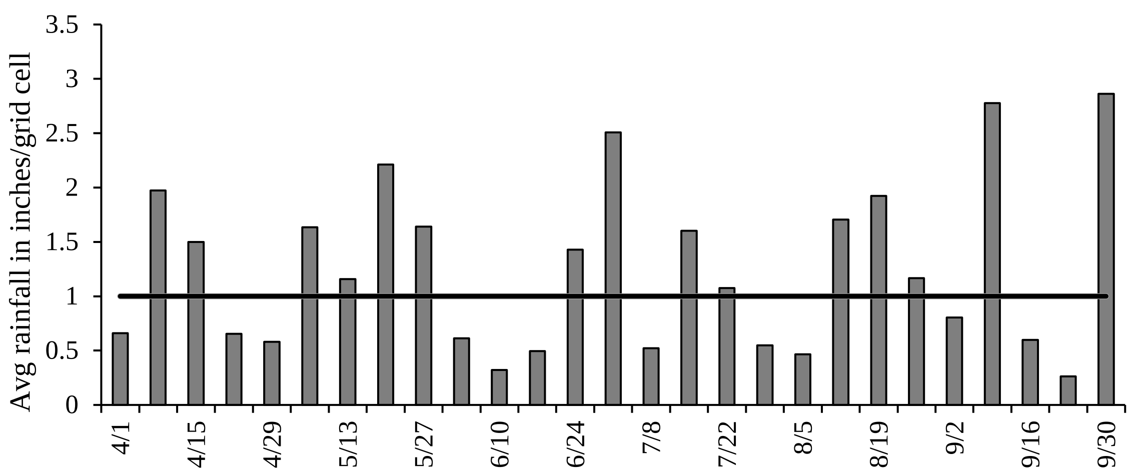


Figure 1.1 Weekly rainfall amounts per grid cell, 2019 (RFC data). Dates represent the Monday of each week. Solid line indicates 1-inch, the amount sufficient to induce egg-hatch.

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 2018 – 2019 was very cold. January through May were colder than normal; in fact, February was 8 degrees colder than the norm, March was 4.3 degrees colder than the norm, April was 1.3 degrees colder, and May was 3.5 degrees colder than the norm (Figure 1.2). Ice-out on Lake Minnetonka occurred on April 20. June, July, and August temperatures were close to normal, and September was 4.7 degrees above the norm.

The snowfall total for the season was 76.8 inches from November-March, which was 22.7 inches above normal. February had 39 inches of snow with another 10.5 inches in March. Even though this winter was categorized as ‘severe’ (State Climatology Office, based on the snow and cold index), weather in the second half of March was ideal for slow melting of the snowpack. On April 4, the frost was out of the ground. Then, for the second year in a row, there was an April blizzard (April 10-12) and 9.8 inches of snow fell. Except for June, precipitation was higher than normal. May was 3.32 inches above normal, July was 2.44 inches above normal, and August was 1.98 inches above normal (Fig. 1.2).

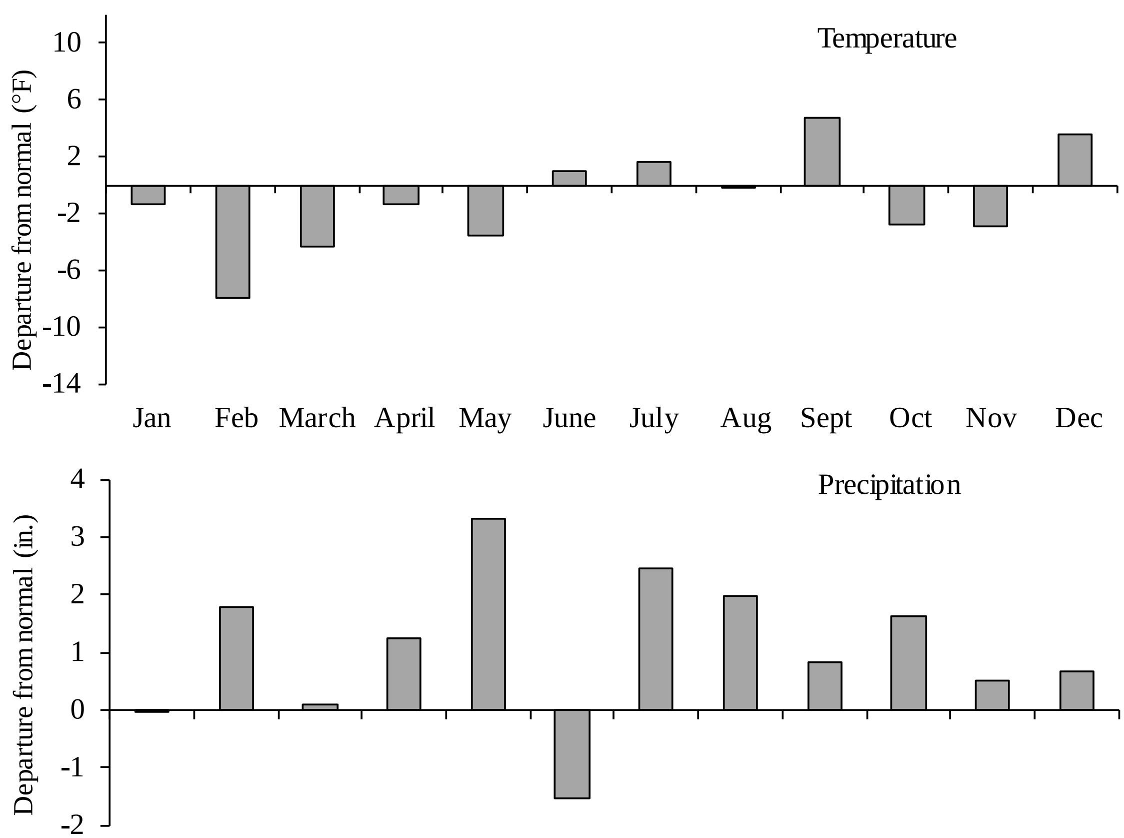
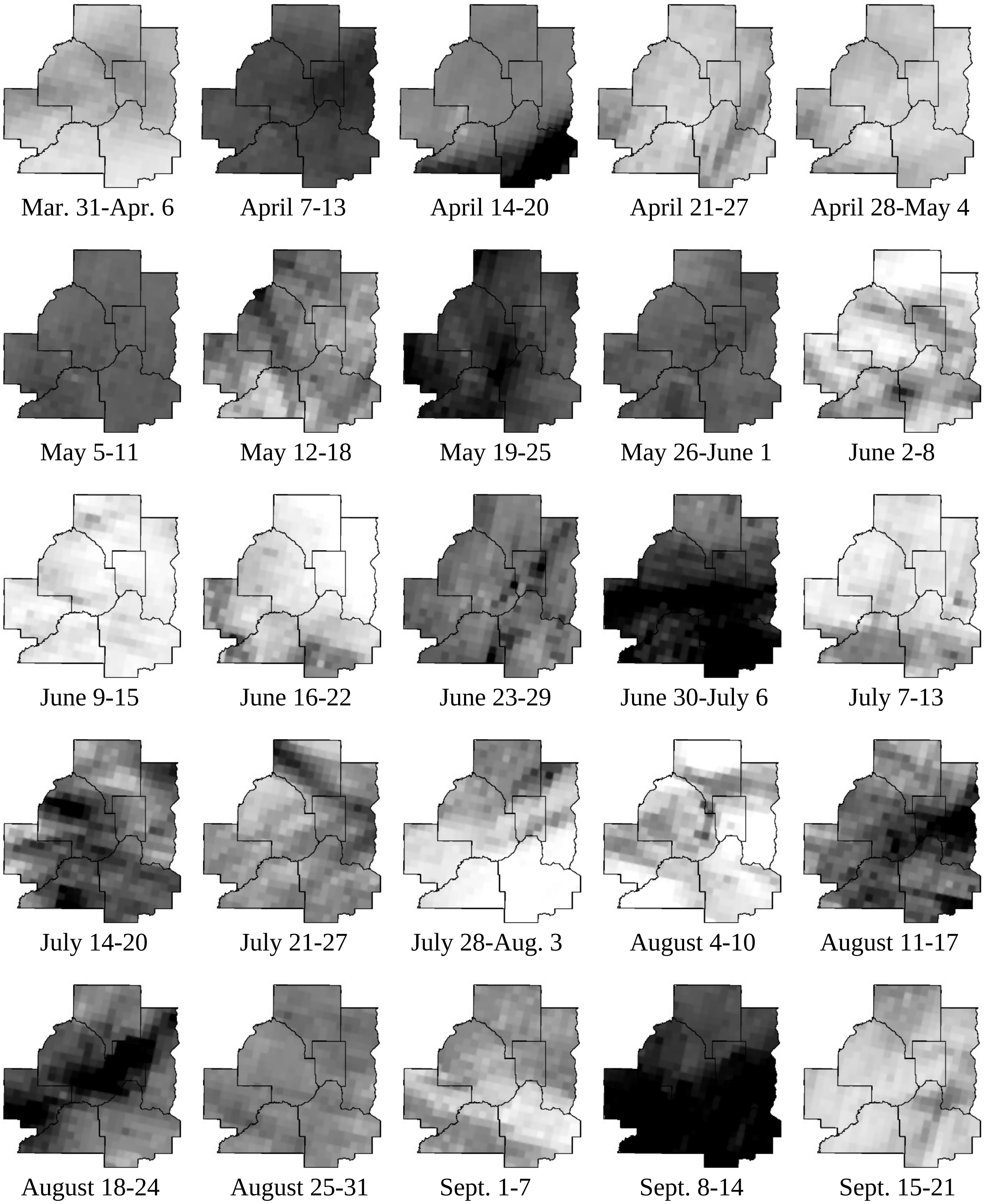


Figure 1.2 Monthly departures from normal for temperature and precipitation January-December, 2019 (source: National Weather Service, Twin Cities Station).

Snow melt and rainfall during April and early May triggered spring *Aedes*, as well as floodwater *Aedes* to hatch. By May 20, the species composition transitioned to floodwater *Aedes*; after that time there were 13 rain events sufficient to produce floodwater *Aedes* hatches (i.e., broods). Three were large, District-wide events, and ten were medium to small 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 through September 2019. 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. Despite heavy rains the week of Sept 8-14, only a small brood developed, mainly because the mosquito eggs had entered diapause (a type of dormancy) and did not hatch.



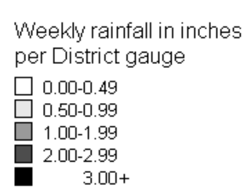


Figure 1.3 Weekly rainfall in inches, 2019. RFC-corrected data using 406 4x4 km grid cells. Inverse distance weighting was the interpolation method used for shading the maps.

Larval Collections

Larval mosquito inspections are conducted to determine if targeted species are present at threshold levels or to obtain species history in development sites. A variety of habitats 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 a minimum of 10 dips is recorded as the number of larvae per dip. Larvae are placed in sample vials and sent to MMCD's Entomology Lab for species identification.

To expedite sample processing for helicopter treatments (air sites), most larvae are identified to genus only; again, this year, spring *Aedes* were identified to species until we determined that most *Aedes* in the sample were summer floodwater species (May 20). *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 2019, lab staff identified 18,584 larval samples (Fig. 1.4).

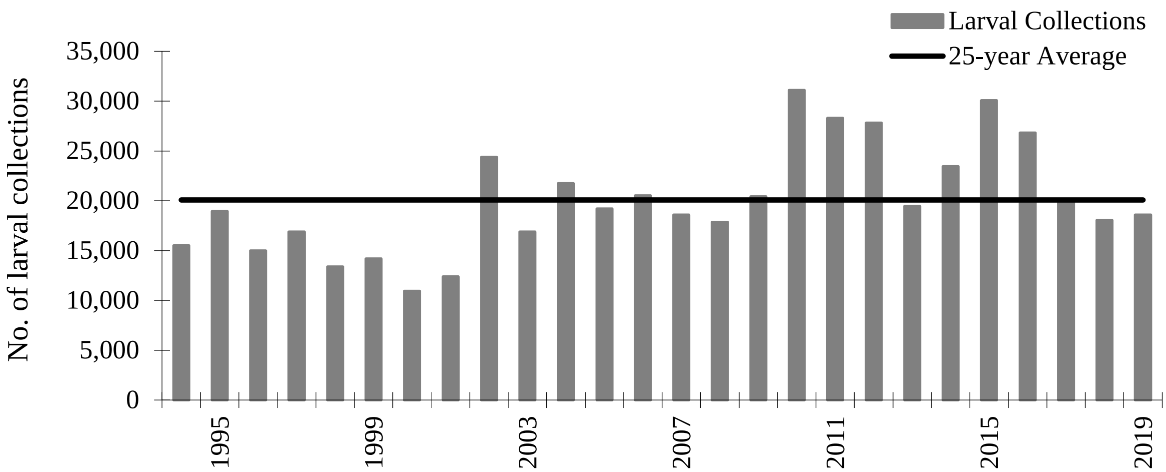


Figure 1.4 Yearly total larval collections, 1994-2019, and 25-year average. Prior to 2015, these totals did not include container samples.

The results of 12,783 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 collected from wetland habitats (24.4% of total) followed by *Ae. cinereus* (23.9%), *Culex territans* (14.8%), and *Cx. restuans* (10.6%), a West Nile virus (WNV) vector. Two spring species [*Ae. excrucians* (8.1%) and *Ae. stimulans* (7.2%)], were in 5th and 6th place. Again in 2019, species level identifications were done for air site samples to identify spring *Aedes* (potential vectors of Jamestown Canyon virus), 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, 2019; the total number of samples processed to species is in parentheses

	Percent of samples where species occurred by facility							
Species	North (2,391)	East (2,727)	South Rosemount (2,307)	South Jordan (2,263)	West Plymouth (1,524)	West Maple Grove (1,571)	Wetland Total (12,783)	Stormwater Structures Total (1,098)
Aedes abserratus	4.31	2.71	0.52	0.13	1.44	1.85	1.90	-
aurifer	0.21	0.18	-	-	-	-	0.08	-
canadensis	1.25	0.88	4.03	1.50	0.72	0.64	1.58	-
cinereus	38.39	23.65	12.44	24.30	16.73	25.21	23.87	0.82
dorsalis	0.08	-	0.04	0.09	0.07	0.38	0.09	-
excrucians	17.86	9.09	3.08	3.58	2.03	10.88	8.05	-
fitchii	2.68	0.88	0.17	0.40	-	0.45	0.84	-
flavescens	-	-	-	-	-	-	-	-
hendersoni	-	-	-	-	-	0.06	0.01	-
implicatus	0.38	0.07	0.04	0.18	0.20	0.32	0.19	-
intrudens	-	-	-	-	-	-	-	-
japonicus	0.08	0.15	0.17	-	0.07	0.06	0.09	12.39
nigromaculis	-	-	-	-	-	-	-	-
provocans	1.25	0.55	-	-	-	0.19	0.38	-
punctor	2.55	2.35	0.26	0.40	1.05	1.53	1.41	-
riparius	1.63	0.95	0.22	0.66	0.66	2.61	1.06	-
spencerii	-	-	-	-	-	-	-	-
sticticus	4.18	0.81	1.39	1.46	0.46	0.70	1.60	0.09
stimulans	10.54	8.91	3.99	6.32	4.07	8.40	7.23	-
triseriatus	0.08	0.11	-	-	0.07	0.06	0.05	1.73
trivittatus	0.71	0.51	5.55	2.52	0.92	0.25	1.83	0.09
vexans	28.94	16.02	41.01	21.74	19.03	17.00	24.44	6.38
Ae. unidentifiable	42.49	37.70	28.70	39.55	47.83	50.92	40.13	8.65
Anopheles earlei	-	-	-	-	-	-	-	-
punctipennis	-	0.22	0.04	-	0.13	-	0.07	-
quadrimaculatus	0.13	0.26	0.09	-	0.13	-	0.11	-
walkeri	-	-	0.04	-	0.00	-	0.01	0.09
An. unidentifiable	0.75	1.98	0.48	0.40	0.79	0.13	0.83	0.64
Culex erraticus	-	-	-	-	-	-	-	-
pipiens	1.00	0.18	0.78	0.53	0.66	0.45	0.59	7.19
restuans	7.32	8.14	16.99	9.46	16.67	5.86	10.55	76.05
salinarius	0.04	0.07	-	0.04	-	0.19	0.05	-
tarsalis	0.25	0.22	1.47	1.33	0.85	0.38	0.74	2.09
territans	9.66	18.37	13.00	16.44	22.44	9.48	14.82	6.10
Cx. unidentifiable	2.43	2.86	3.99	4.07	5.38	2.36	3.43	44.81
Culiseta inornata	6.90	8.76	10.79	7.69	7.68	6.05	8.13	1.73
melanura	-	-	-	-	-	-	-	-
minnesotae	0.29	0.81	0.04	0.09	0.20	0.13	0.29	-
morsitans	0.13	0.04	-	-	-	-	0.03	-
Cs. unidentifiable	2.13	3.08	0.39	0.66	2.56	1.46	1.73	0.27
Or. signifera	-	-	-	-	-	-	-	-
Ps. ciliata	-	-	-	-	-	-	-	-
columbiae	-	-	-	-	-	-	-	-
ferox	0.04	0.04	0.13	0.09	-	-	0.05	-
horrida	-	-	-	0.04	-	-	0.01	-
Ps. unidentifiable	0.08	0.04	0.43	0.22	0.20	0.06	0.17	-
Ur. sapphirina	1.97	2.86	0.78	0.93	1.71	0.38	1.53	0.09

Adult Mosquito Collections

The District employs 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 20 weeks, May 13-September 24.

Sweep Nets | CO_2 Traps

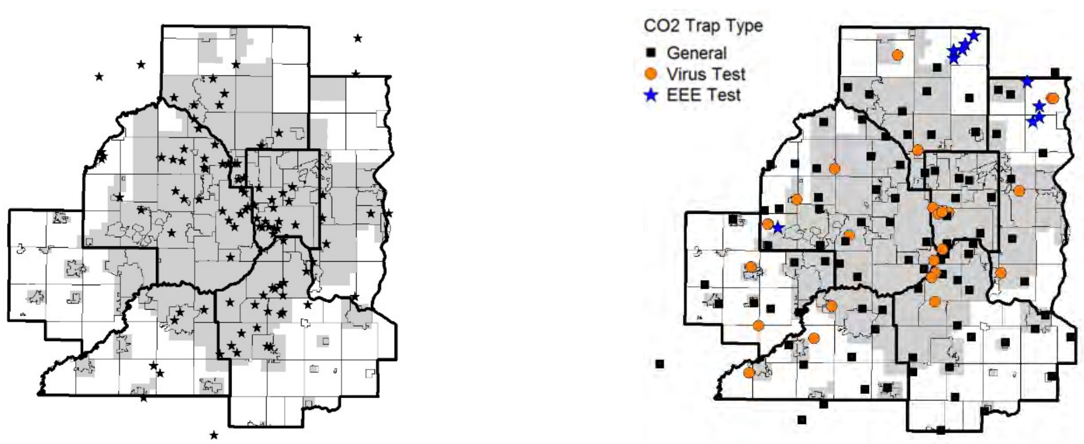


Figure 1.5 Locations of weekly sweep net and CO_2 traps used to monitor general mosquito populations and disease vectors (virus test and EEE test), 2019.

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. The number of collectors varied from 41-73 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 1,185 collections containing 971 mosquitoes in 2019. The average number of summer *Aedes* collected in the evening sweep net collections in 2019 was much lower than in 2018 as were *Cq. perturbans*, and *Cx. tarsalis* (Table 1.2). Only spring *Aedes* species were collected in higher numbers than the past four years. All species collected were well below the 19-year average.

Table 1.2 Average number of mosquitoes collected per evening sweep net collection within the District, 2015-2019 and 19-year average, 2000-2018 (± 1 SE)

Year	Summer *Aedes*	*Cq. perturbans*	Spring *Aedes*	*Cx. tarsalis*
2015	1.27	0.29	0.05	0.006
2016	1.55	0.37	0.03	0.005
2017	0.79	0.49	0.01	0.001
2018	1.50	0.22	0.03	0.009
2019	0.55	0.14	0.09	0.003
19-yr Avg.	1.68 (±0.31)	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 2019, we placed 136 traps at 123 locations (twelve of these locations have low traps paired with elevated traps) to allow maximum coverage of the District (Figure 1.5). An additional five 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 2,299 District low CO_2 trap collections taken contained 547,019 mosquitoes in 2019. The total number of these traps operated weekly varied from 112-118. 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. Populations levels were slightly higher than last year, but still below the 19-year average. *Coquillettidia perturbans* populations were normal and well below the high levels detected in 2017. Captures of spring *Aedes* increased in 2019 and were closer to the long-term average. *Culex tarsalis* numbers were less than half the average. This was the fifth consecutive year that *Cx. tarsalis* numbers were well below the District's 19-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, 2015-2019 and 19-year average, 2000-2019 (± 1 SE)

Year	Summer *Aedes*	*Cq. perturbans*	Spring *Aedes*	*Cx. tarsalis*
2015	115.7	37.4	1.7	1.0
2016	207.6	51.0	1.3	1.4
2017	134.8	140.8	2.5	0.6
2018	153.4	52.6	5.3	0.8
2019	160.1	66.1	6.5	0.7
19-yr Avg.	206.2 (±28.8)	52.9 (±7.7)	7.9 (±1.9)	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.

Spring *Aedes* populations were detected from May 28-July 29 and were mostly confined to a few locations on the outer edges of the District (Figure 1.6). Typically, higher levels of spring *Aedes* are found in Anoka and Washington counties. Western Hennepin and Carver counties also had higher levels.

The first detections of the summer *Aedes* occurred June 3 (Fig. 1.7). Very high levels were detected June 10-June 17. Local infestations were detected from June 24-July 1. Following heavy rains, widespread emergence occurred through July. Notably, only Anoka County was spared the significant, mosquito-producing rains. Summer *Aedes* were concentrated in local areas from August through September.

Coquillettidia perturbans was first detected June 10 (Figure 1.8). Small pockets of higher levels occurred up until the peak emergence July 8-July 15; populations declined thereafter. The highest levels occurred outside of P1.

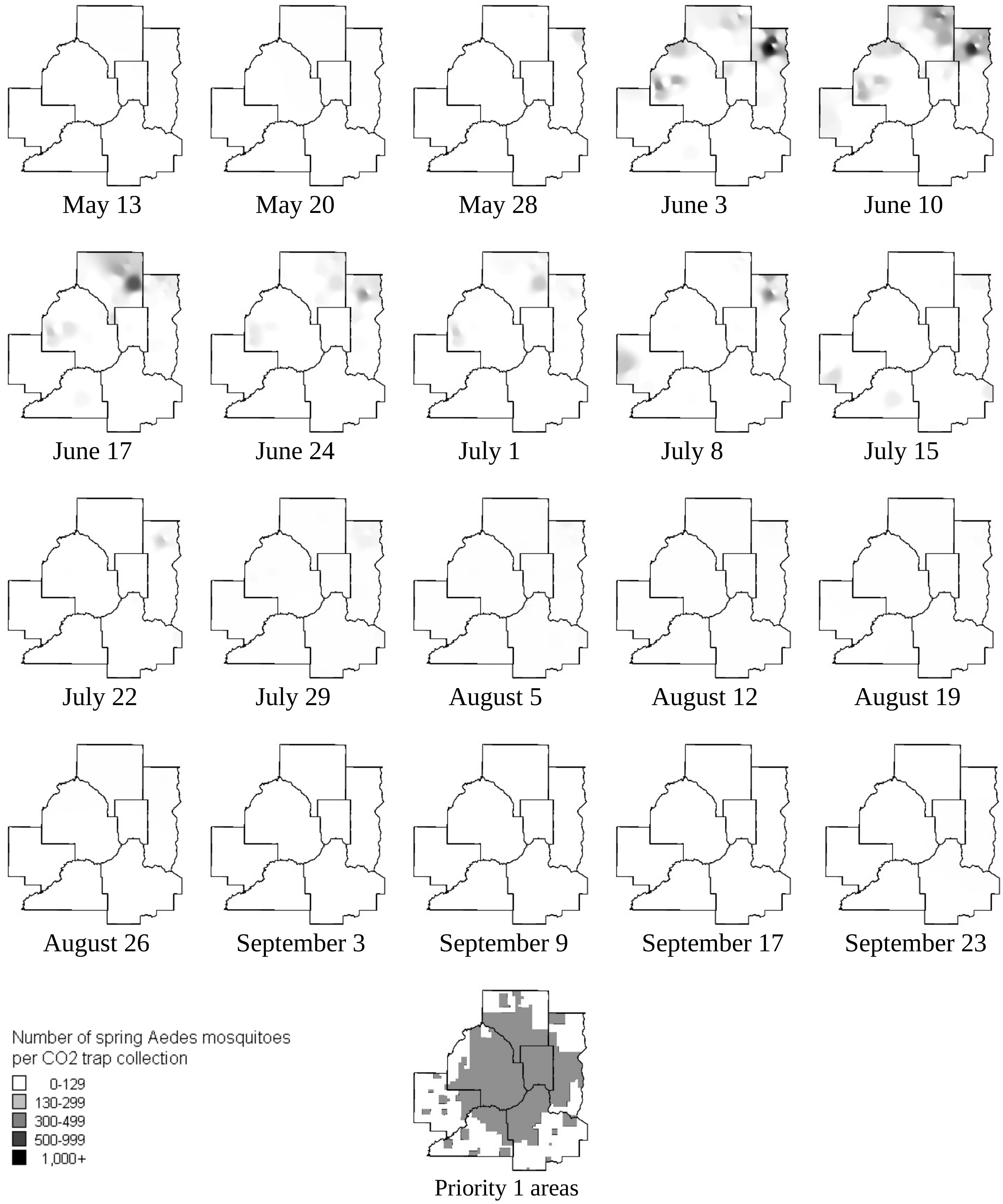


Figure 1.6 Number of spring *Aedes* in District low (5 ft) CO_2 trap collections, 2019. The number of traps operated per night varied from 112-118. Inverse distance weighting was the interpolation method used for shading the maps. Treatment threshold is >130 mosquitoes/trap night. Priority 1 shaded area map for reference.

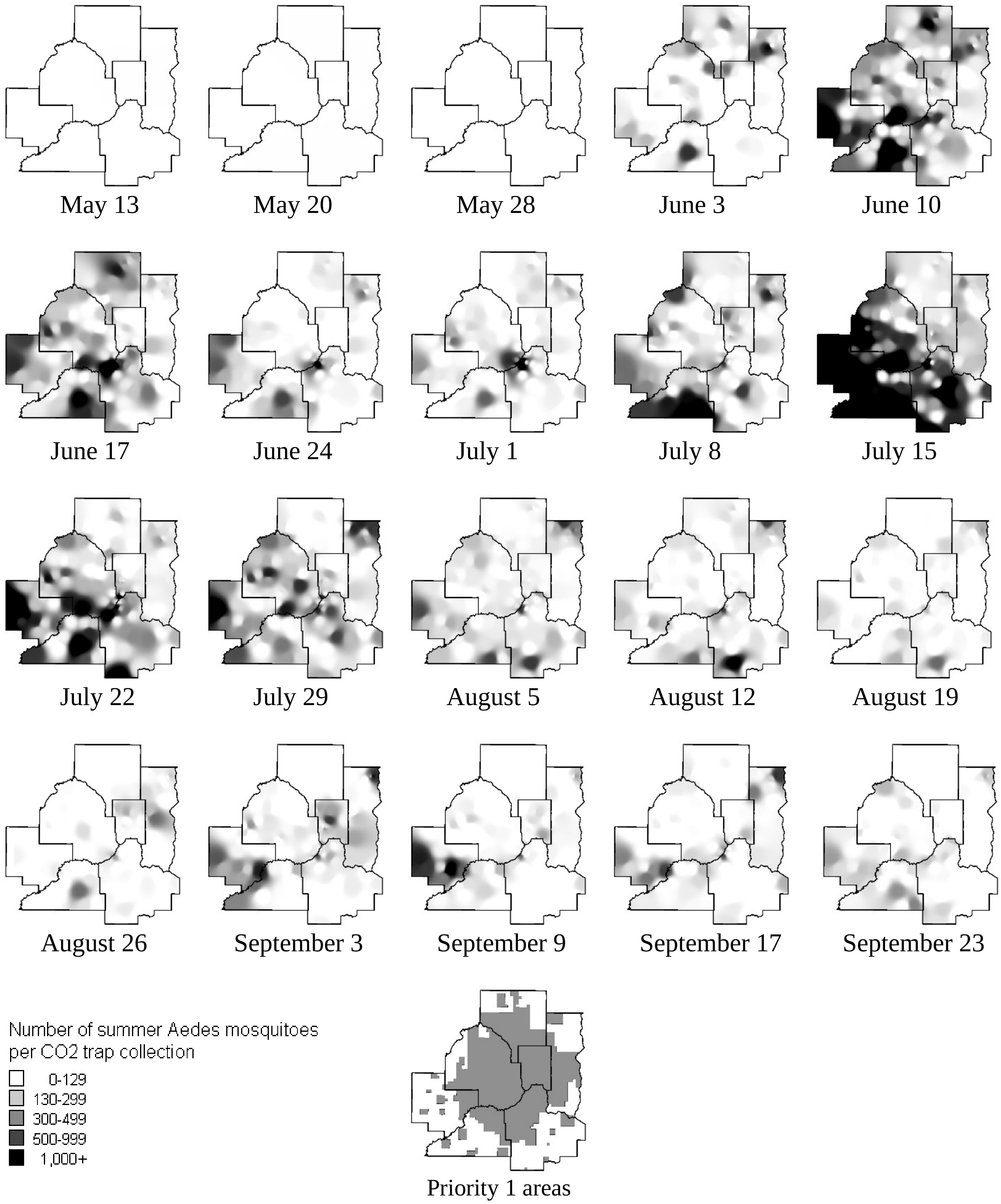


Figure 1.7 Number of summer *Aedes* in District low (5 ft) CO_2 trap collections, 2019. The number of traps operated per night varied from 112-118. Inverse distance weighting was the algorithm used for shading of maps. Treatment threshold is >130 mosquitoes/trap night. Priority 1 area map for reference.

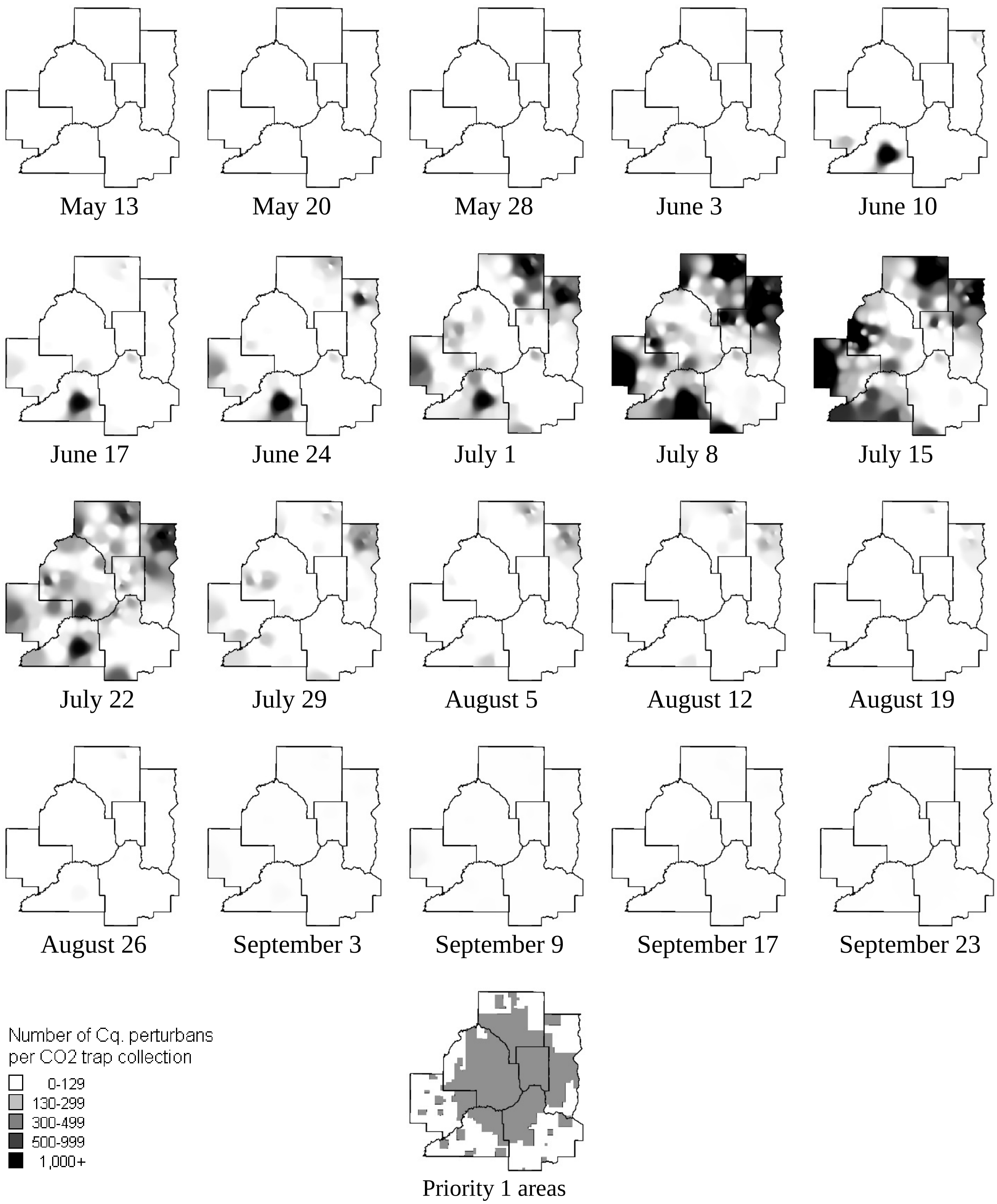


Figure 1.8 Number of *Cq. perturbans* in District low (5 ft) CO_2 trap collections, 2019. The number of traps operated per night varied from 112-118. Inverse distance weighting was the algorithm used for shading of maps. Treatment threshold is >130 mosquitoes/trap night. Priority 1 area map for reference.

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 2019, sampling with CO_2 traps and sweep nets started May 13. Many nights were well above the mosquito flight threshold temperature and sampling continued as scheduled.

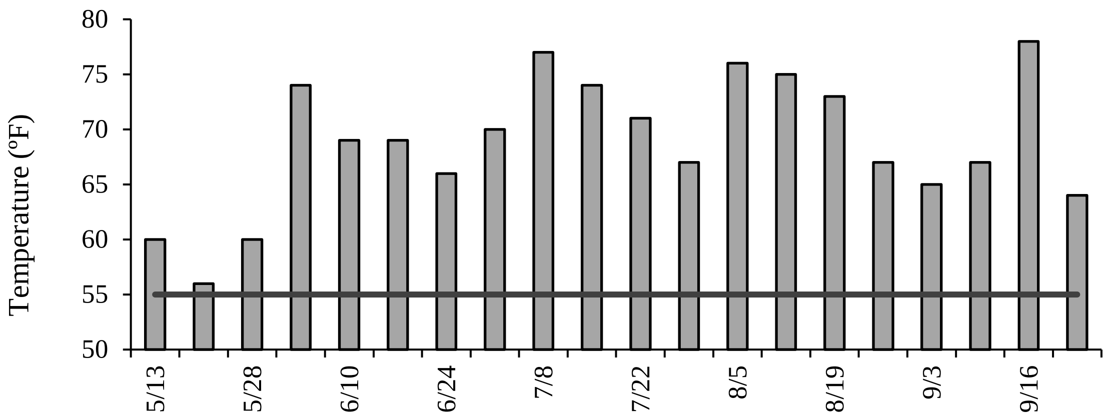


Figure 1.9 Temperature at 9:00 p.m. on actual dates of Monday night surveillance, 2019 (source: National Weather Service, Twin Cities Station). The black horizonal line indicates the mosquito flight threshold, 55°F.

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 from early May through September. Adult spring *Aedes* were first detected May 28 in both sweep and CO_2 samples. Highest levels in sweep nets weren't detected until July 1; the average date for the spring *Aedes* peak in sweep samples is mid-June (Fig. 1.10). Captures in CO_2 traps were first detected on May 28 and sharply increased the following week (Fig. 1.11). The population peaked June 10 and declined thereafter.

Summer *Aedes* were first detected in sweep nets and CO_2 traps on June 3 (Fig. 1.10 and Fig. 1.11, respectively). A steady increase was detected in sweep samples through June, the highest levels were detected July 15, and were at low levels through the remainder of July and August. Except for September 17, the summer *Aedes* captured in sweep samples were well below the 19-year average. Mosquito levels in CO_2 traps were below the 19-year average, except for a very high peak when the average mosquitoes collected per trap was over 1,300 (Fig. 1.11).

The single generation *Cq. perturbans* was initially detected June 10 for both the sweep net and CO_2 trap sampling. Sweep nets detected small levels of *Cq. perturbans* through June and a sharp increase was detected July 8 with the population peak occurring on July 22; *Cq. perturbans* were collected in numbers below the 19-year average for sweep netting (Fig. 1.10). Highest levels in CO_2 traps occurred July 15 and were well above the 19-year average (Fig. 1.11). Populations quickly fell thereafter. Looking at priority areas explains the large peak experienced on July 15. P1, which gets full larval control, had very low populations compared to P2, which had very high levels of adult mosquitoes (Figure 1.12).

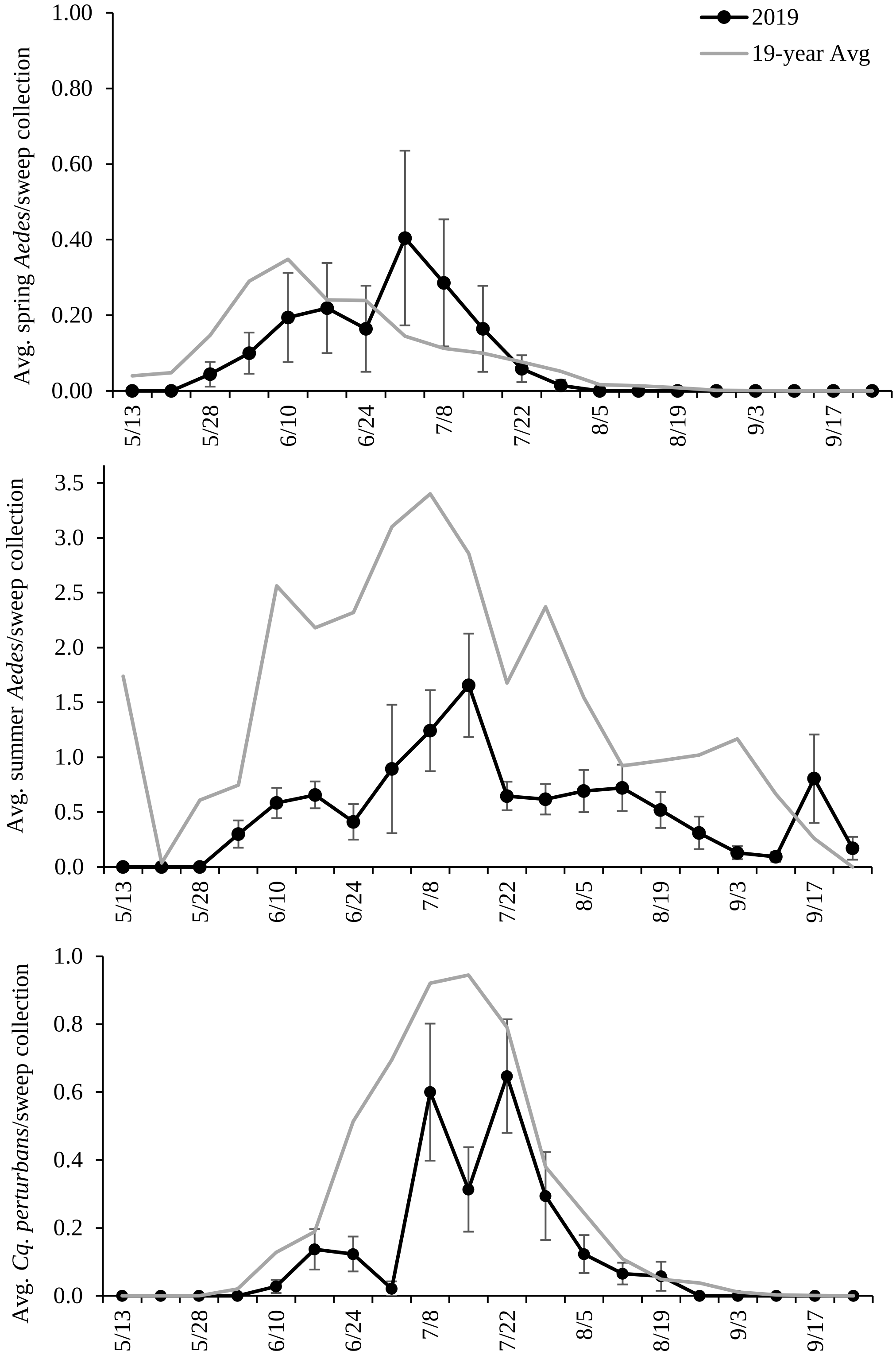


Figure 1.10 Average number of spring *Aedes*, summer *Aedes*, and *Cq. perturbans* per sweep net collection, 2019 vs. 19-year average. Dates are the Mondays of each week. Error bars equal ± 1 standard error of the mean.

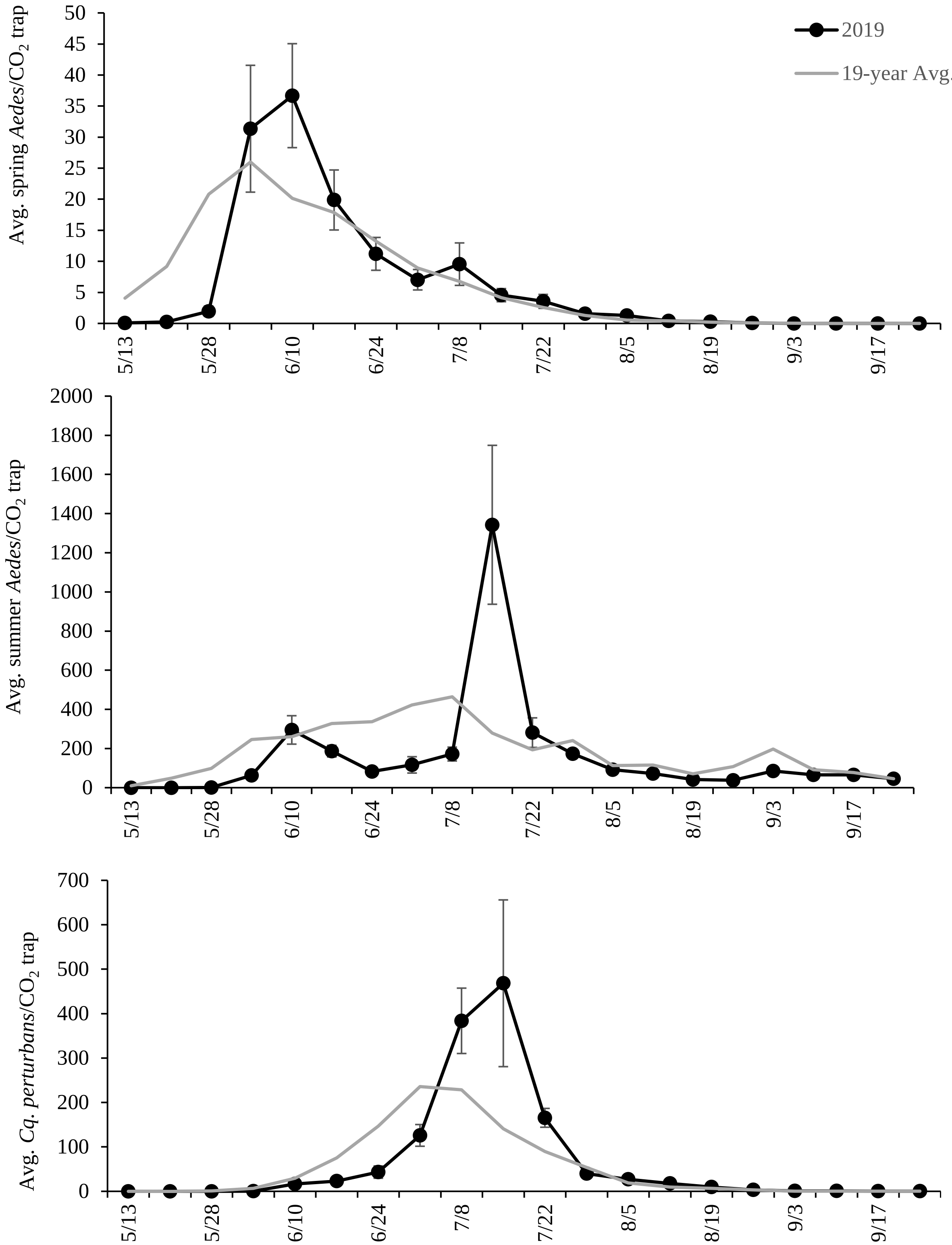


Figure 1.11 Average number of spring *Aedes*, summer *Aedes*, and *Cq. perturbans* per CO_2 trap, 2019 vs. 19-year average. Dates are the Mondays of each week. Error bars equal ± 1 standard error of the mean.

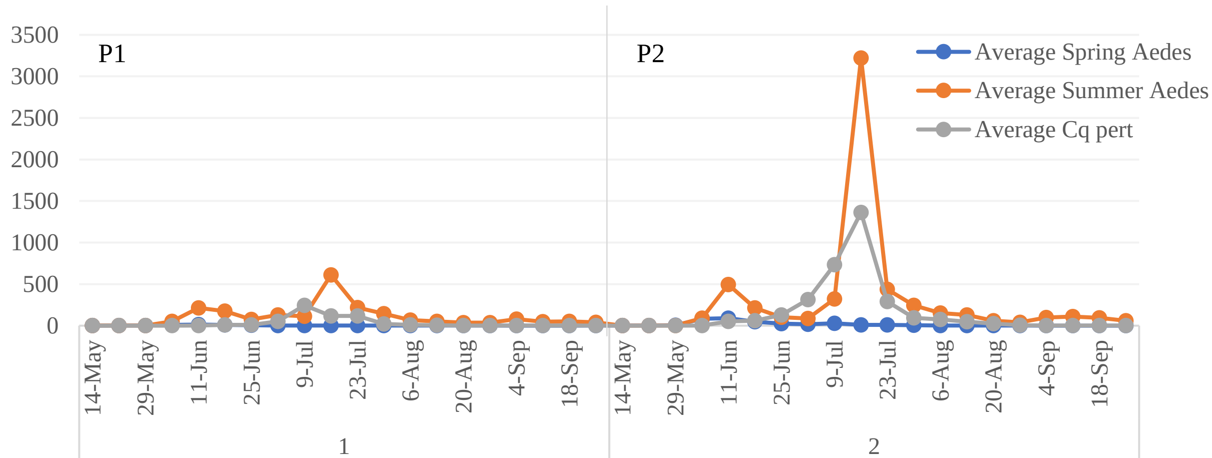


Figure 1.12 Average number of spring *Aedes*, summer *Aedes*, and *Cq. perturbans* per CO_2 trap, 2019 in P1 and P2.

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 1965-2019. The CA1 trap started in 1991. Trap 13 has been at MMCD's Jordan Office location since 1998.

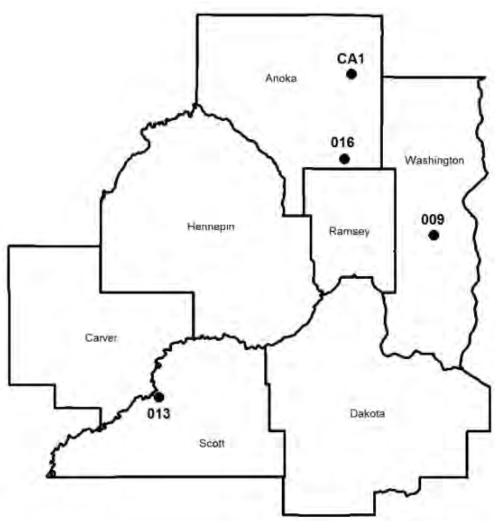


Figure 1.13 NJ light trap locations, 2019.

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* (38% of all female mosquitoes captured), *Ae. vexans* (31.9%), *Ae. abserratus/punctor* (9.9% includes *Ae. abserratus*, *Ae. punctor*, and unidentifiable *abserratus/punctor*), *Ae. cinereus* (8%), and *Anopheles walkeri* (6.3%) (Table 1.4). The Carlos Avery trap (CA1) collected 88% of all females collected followed by Lake Elmo (6.5%, Trap 9), Jordan (4.2%, Trap 13), and Lino Lakes (1.4%, Trap 16).

Trap 9, located in Washington County, was dominated by *Aedes vexans*. *Coquillettidia perturbans* and *An. quadrimaculatus* were the next most abundant species. Of the four NJ trap locations, this location also captured the most *Ae. japonicus* (10 of 18).

Trap 13 is located in Scott County. The trapping location is adjacent to a river floodplain with nearby cropland in a rural landscape. The most abundant species collected were *Ae. vexans* and *Cq. perturbans*.

Trap 16 is located in southeastern Anoka County. The most abundant species collected in this trap was *Ae. vexans*. Normally this trap collects many more *Ae. vexans* and *Cq. perturbans*. Many of the large rain events did not occur in Anoka County, and likely resulted in lower production of *Ae. vexans*; however, *Cq. perturbans* production is not dependent on current year rains and only 15 were collected over the course of the summer. We will investigate whether there were trap inconsistencies or perhaps habitat modifications near the trap.

CA1, located in the northern part of the District in 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-six percent of all *Coquillettidia perturbans,* 72% of *Ae.* vexans, 99.8 % of the spring *Aedes* species of *Ae. abserratus* and *Ae. punctor*, 99.4% *Ae. cinereus*, and 99.4% *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 4 - September 20, 2019

	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	140	140	138	135	553	Total	Night
Ae. abserratus	1	0	1	554	556	2.02%	1.01
atropalpus	0	0	0	0	0	0.00%	0.00
aurifer	0	0	0	0	0	0.00%	0.00
canadensis	0	0	0	24	24	0.09%	0.04
cinereus	2	7	5	2,190	2,204	7.99%	3.99
dorsalis	0	0	0	0	0	0.00%	0.00
excrucians	1	1	0	9	11	0.04%	0.02
fitchii	0	0	0	4	4	0.01%	0.01
hendersoni	0	0	0	0	0	0.00%	0.00
implicatus	0	0	0	0	0	0.00%	0.00
japonicus	10	0	0	8	18	0.07%	0.03
nigromaculus	0	0	0	0	0	0.00%	0.00
punctor	0	0	0	223	223	0.81%	0.40
riparius	0	0	0	1	1	0.00%	0.00
spencerii	0	0	0	0	0	0.00%	0.00
sticticus	3	11	0	31	45	0.16%	0.08
stimulans	0	0	0	0	0	0.00%	0.00
provocans	0	0	0	0	0	0.00%	0.00
triseriatus	2	1	0	0	3	0.01%	0.01
trivittatus	71	10	0	516	597	2.16%	1.08
vexans	1,169	983	299	6,336	8,787	31.85%	15.89
abserratus/punctor	1	2	1	1,934	1,938	7.02%	3.50
Aedes unidentifiable	77	7	6	81	171	0.62%	0.31
Spring *Aedes* unident.	0	0	1	11	12	0.04%	0.02
Summer *Aedes* unident.	0	1	0	0	1	0.00%	0.00
An. barberi	0	0	0	0	0	0.00%	0.00
earlei	0	0	0	0	0	0.00%	0.00
punctipennis	10	2	0	14	26	0.09%	0.05
quadrimaculatus	116	27	0	49	192	0.70%	0.35
walkeri	9	1	0	1,720	1,730	6.27%	3.13
An. unidentifiable	35	4	0	37	76	0.28%	0.14
Cx. erraticus	0	0	0	0	0	0.00%	0.00
pipiens	0	0	0	0	0	0.00%	0.00
restuans	13	6	2	83	104	0.38%	0.19
salinarius	0	0	0	0	0	0.00%	0.00
tarsalis	1	6	1	1	9	0.03%	0.02
territans	15	6	4	16	41	0.15%	0.07
Cx. unidentifiable	19	1	1	13	34	0.12%	0.06
Cx. pipiens/restuans	41	6	2	33	82	0.30%	0.15
Cs. inornata	15	7	0	10	32	0.12%	0.06
melanura	0	0	0	1	1	0.00%	0.00
minnesotae	3	0	0	71	74	0.27%	0.13
morsitans	1	0	0	13	14	0.05%	0.03
Cs. unidentifiable	0	0	0	0	0	0.00%	0.00
Cq. perturbans	186	169	15	10,127	10,497	38.04%	18.98
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	38	10	3	11	62	0.22%	0.11
Unidentifiable	5	1	3	14	23	0.08%	0.04
Female Total	1,844	1,269	344	24,135	27,592	100.00%	49.90
Male Total	495	245	143	7,429	8,312		
Grand Total	2,339	1,514	487	31,564	35,904		

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 higher than 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 2019 was 57.1 *Cq. perturbans* per CO_2 trap, but the actual rate was 66.1 (Figure 1.14). The predicted number of *Cq. perturbans* collected per CO_2 trap in 2020 is 90.2.

Retroactively fitting the model created using the entire 2000-2019 dataset shows that this simple model which includes only the previous years' precipitation and average number of *Cq. perturbans* explains approximately 80% of the variation in the average abundance collected in CO_2 traps the following year (Figure 1.15).

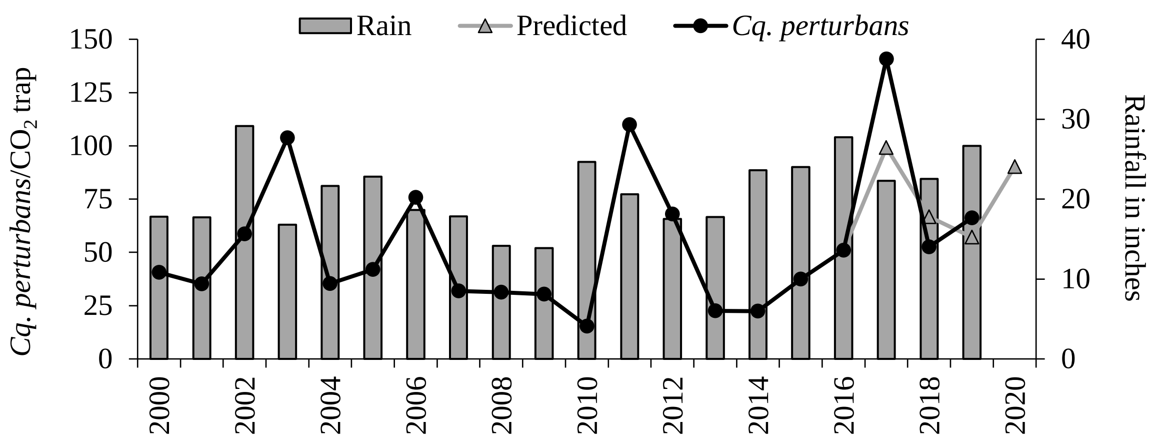


Figure 1.14 Average number of *Coquillettidia perturbans* in CO_2 traps and average seasonal rainfall per gauge, 2000-2019. The gray line shows the predicted amounts for 2017 and beyond.

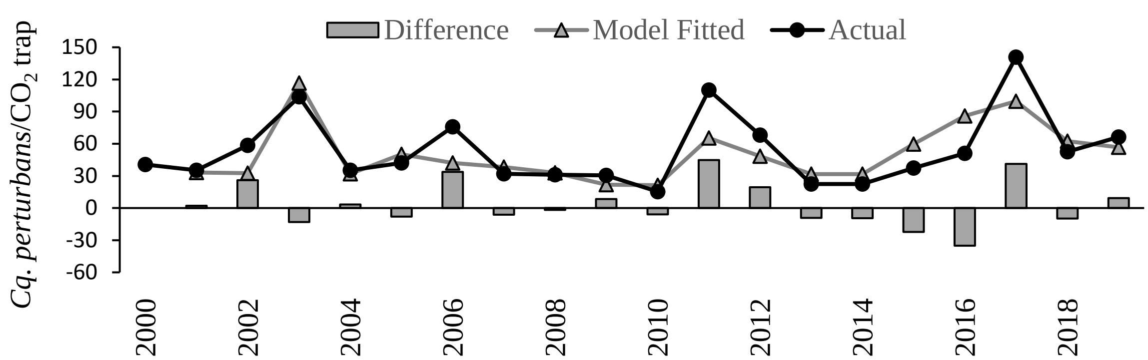


Figure 1.15 Difference between fitted model and actual *Cq. perturbans* counts per CO_2 trap.

Rare Detections

With our Monday Night Network, we monitor other species which are considered uncommon or rare in Minnesota. *Culex erraticus*, *Anopheles earlei*, *Anopheles 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 collected in 2019.

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. 1.16).

Psorophora ferox and *Ps. horrida* numbers have also been increasing (Fig. 1.17). 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*. A possible reason for increasing numbers is favorable conditions that allow these species to expand their ranges northward. Maps representing the abundance of adult *Psorophora* species collected during our Monday Night Network from the previous 15 years were created by interpolating counts from our CO_2 trap, gravid, and sweep net sampling (Fig. 1.18). Relative abundance of either *Ps. ferox* or *Ps. horrida* varies yearly, but looking at the combined distribution of this genera in the District shows hotspots in southern Dakota County, northern Washington County, and consistent collections in western Carver County. Many of the locations with the highest abundance of these species occur in P2, which further demonstrates the effectiveness of our larval control efforts in P1.

We have noted other species that were once common are now becoming uncommon or rare. *Anopheles earlei*, for example, used to be detected regularly (Fig. 1.19). Ten years ago, we collected 100 *An. earlei* adults in our Monday Night Network. Over the next five years we only collected 34 in total, and in the last 4 years we have not captured any adult *An. earlei*. This contrasts with the increased numbers of *An. quadrimaculatus* and *An. walkeri* that have been collected in the District. *Anopheles quadrimaculatus* spread from east to west across the District in the mid-2000s (Fig. 1.20). Presently, this species can be found in most areas of the District with suitable habitat and is more abundant in P2, and along the floodplains of our major rivers. The cumulative historic records for *An. quadrimaculatus* show the absence of this species from only the most urban areas of the District.

2020 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.

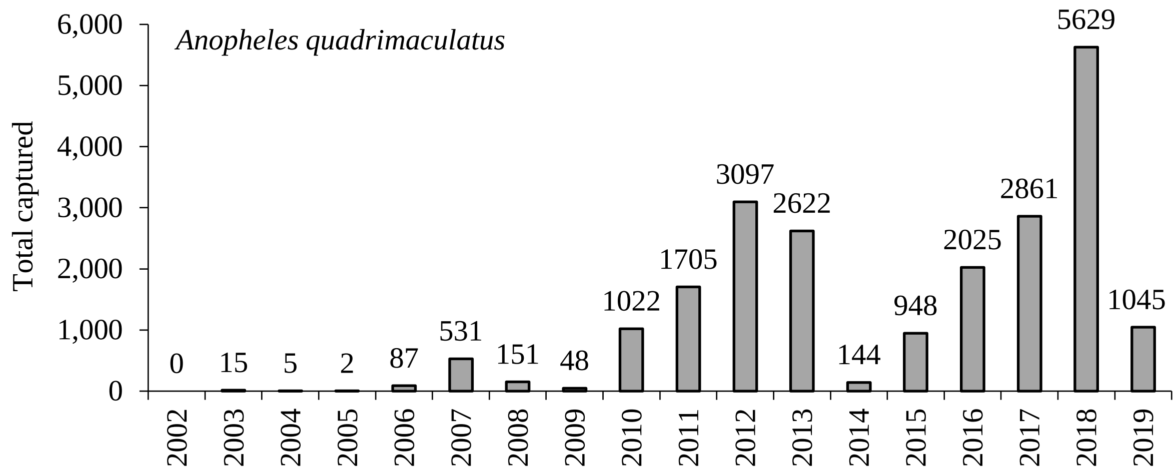


Figure 1.16 Total yearly *An. quadrimaculatus* collected from Monday Night CO_2 traps (low, high, and any outside District), 2002-2019.

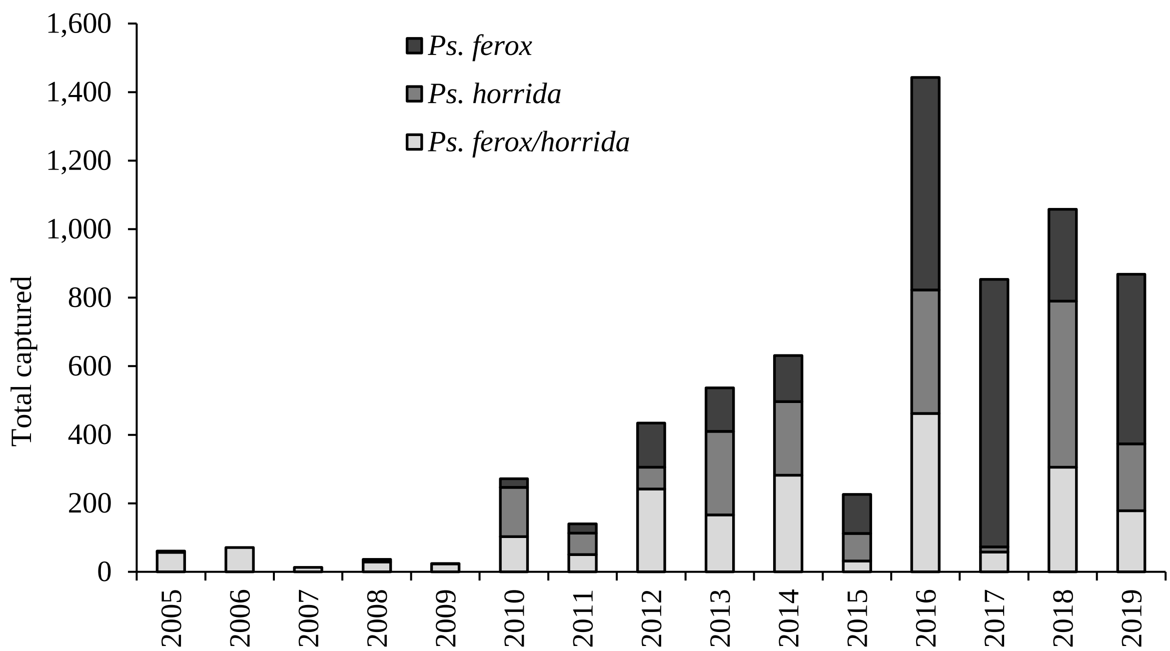


Figure 1.17 Total yearly *Ps. ferox*, *Ps. horrida*, and *Ps. ferox/horrida* collected from Monday Night CO_2 traps (low, high, and any outside District), 2005-2019.

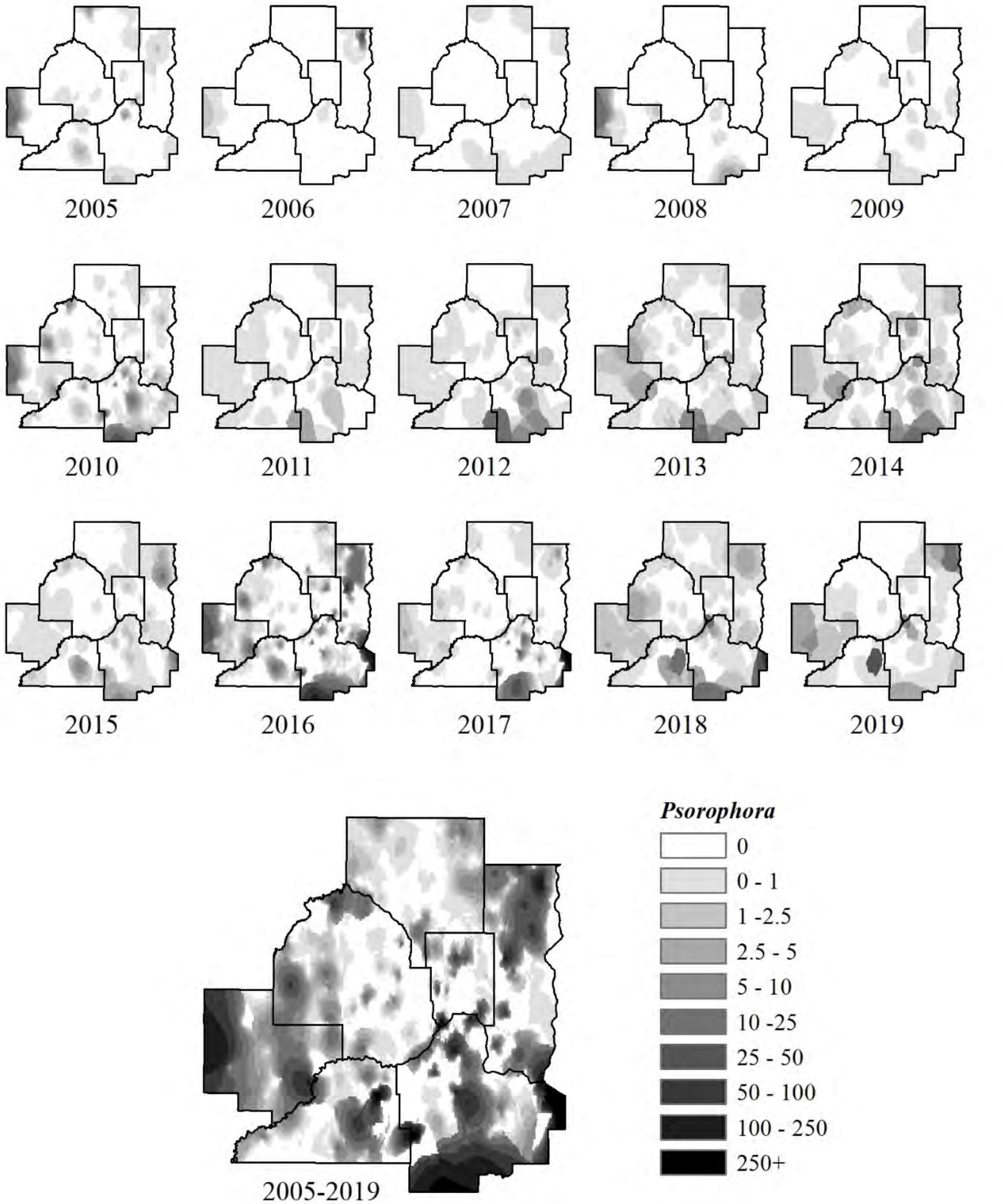


Figure 1.18 Interpolated yearly adult collections for adult *Psorophora* species from the Monday Night Network collections (CO_2 traps, sweeps, gravid traps).

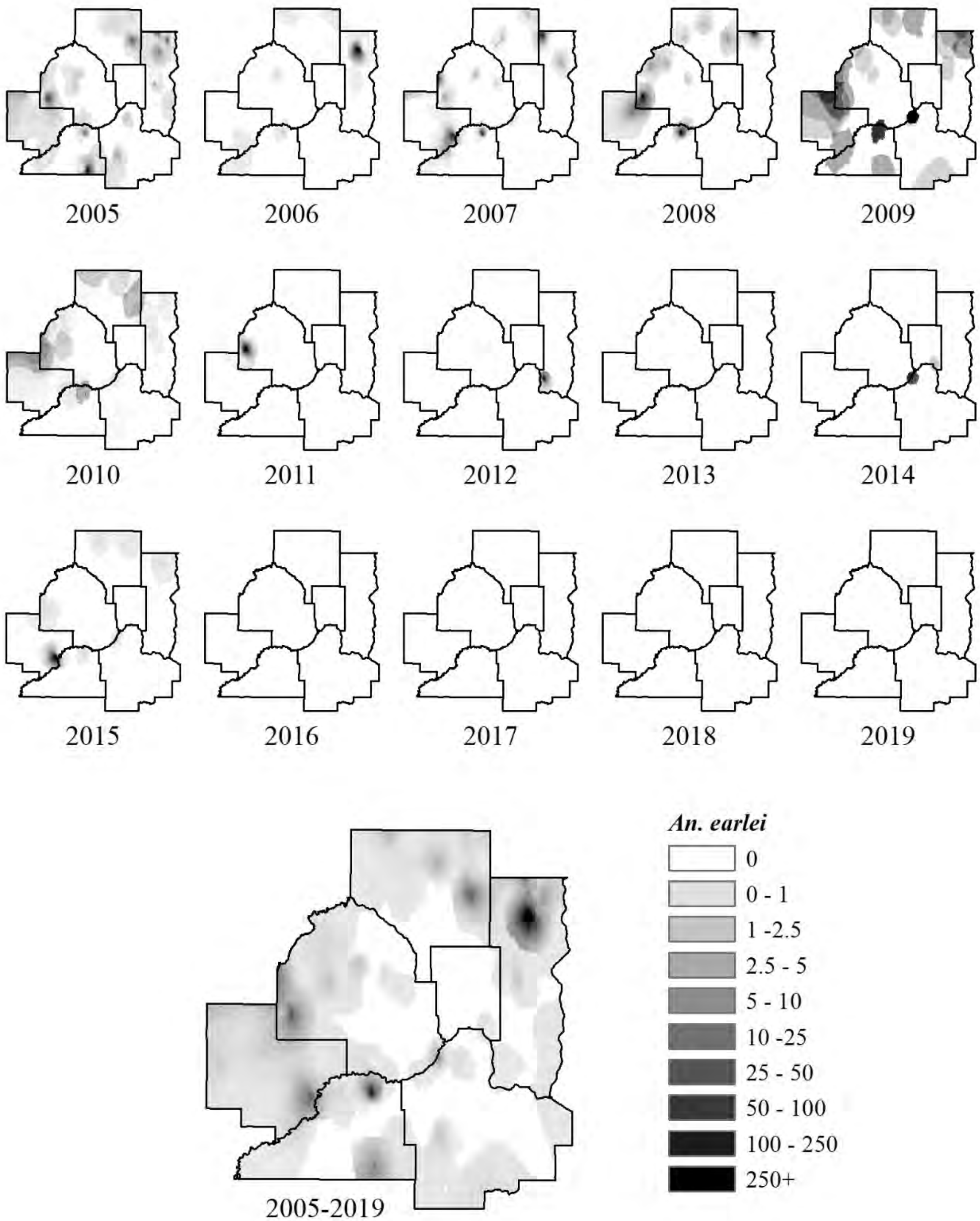


Figure 1.19 Interpolated yearly adult collections for adult *An. earlei* from the Monday Night Network collections (CO_2 traps, sweeps, gravid traps).

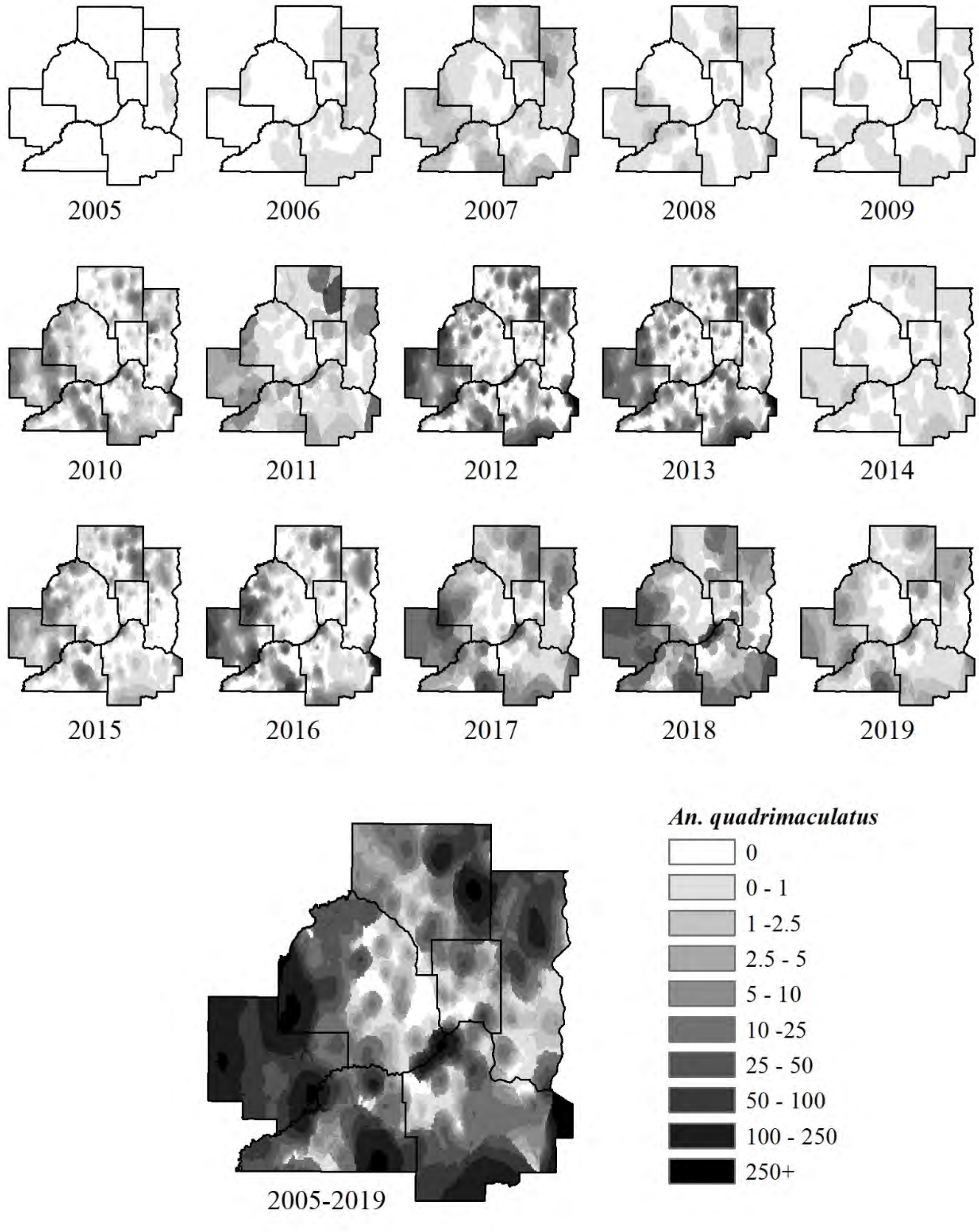


Figure 1.20 Interpolated yearly adult collections for adult *An. quadrimaculatus* from the Monday Night Network collections (CO_2 traps, sweeps, gravid traps).

Chapter 2 Mosquito-borne Disease

2019 Highlights

- There were no La Crosse encephalitis cases in Minnesota
- Jamestown Canyon virus caused 13 illnesses in Minnesota with four in District residents
- WNV illnesses were confirmed in three Minnesotans, two occurred in District residents
- WNV detected in five District mosquito samples
- Collected and recycled 9,763 tires

2020 Plans

- Continue to provide surveillance and control for La Crosse encephalitis prevention
- Work with others to better understand Jamestown Canyon virus transmission
- Continue catch basin larvicide treatments to manage WNV vectors
- Communicate disease prevention strategies to other local governments
- Continue surveillance for WNV and other mosquito-borne viruses
- Continue to monitor for *Ae. albopictus* and other exotic species
- Continue *Cs. melanura* surveillance and evaluate control options for EEE prevention

Background

District staff provide a variety of disease surveillance and control services, as well as public education, to reduce the risk of mosquito-borne illnesses such as La Crosse encephalitis (LAC), western equine encephalitis (WEE), eastern equine encephalitis (EEE), Jamestown Canyon virus (JCV), and West Nile 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.

2019 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 2019, District staff recycled 9,763 tires that were collected from the field (Table 2.1). Since 1988, the District has recycled 688,553 tires. In addition, MMCD eliminated 1,611 containers and filled 395 tree holes (Table 2.1). This reduction of larval habitats occurred through inspection of public and private properties and while conducting a variety of mosquito, tick, and black fly surveillance and control activities.

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

Year	Tires	Containers	Tree holes	Total
2008	16,229	1,615	93	17,937
2009	39,934	8,088	529	48,551*
2010	23,445	5,880	275	29,600
2011	17,326	3,250	219	20,795
2012	21,493	3,908	577	25,978
2013	17,812	2,410	386	20,608
2014	21,109	3,297	478	24,884
2015	24,127	2,595	268	26,990
2016	18,417	1,690	261	20,368
2017	14,304	1,809	298	16,411
2018	9,730	1,993	478	12,201
2019	9,763	1,611	395	11,769

*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 2019, there were 49 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 2019, MMCD staff collected 1,170 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 191 aspirator samples. Adulticides were applied to wooded areas in 70 of those cases. Adult *Ae. triseriatus* were captured in 342 of 1,055 wooded areas sampled. The mean *Ae. triseriatus* capture was higher than in 2018, but similar to 2017 (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
2000	1,037	575	55.4	1,912	1.94
2001	1,222	567	46.4	2,155	1.32
2002	1,343	573	42.7	2,058	1.70
2003	1,558	470	30.2	2,676	1.20
2004	1,850	786	42.5	3,101	1.34
2005	1,993	700	35.1	2,617	0.84
2006	1,849	518	28.0	2,680	0.78
2007	1,767	402	22.8	2,345	0.42
2008	1,685	495	29.4	2,429	0.64
2009	2,258	532	24.0	3,125	0.56
2010	1,698	570	33.6	2,213	0.89
2011	1,769	566	32.0	2,563	0.83
2012	2,381	911	38.3	3,175	1.10
2013	2,359	928	39.3	2,905	1.22
2014	2,131	953	44.7	2,543	1.45
2015	1,272	403	31.7	1,631	0.72
2016	1,268	393	31.0	1,590	0.75
2017	1,173	361	30.8	1,334	0.98
2018	1,211	374	30.9	1,394	0.75
2019	1,055	342	32.4	1,170	0.97

Aspirator sampling began during the week of June 3 and continued through the week of August 26. Weekly mean collections of *Ae. triseriatus* remained near the long-term average most of the season, although there was a midseason dip in July (Fig. 2.1). We observed the season peak of 1.7 *Ae. triseriatus* per sample during the week of June 24.

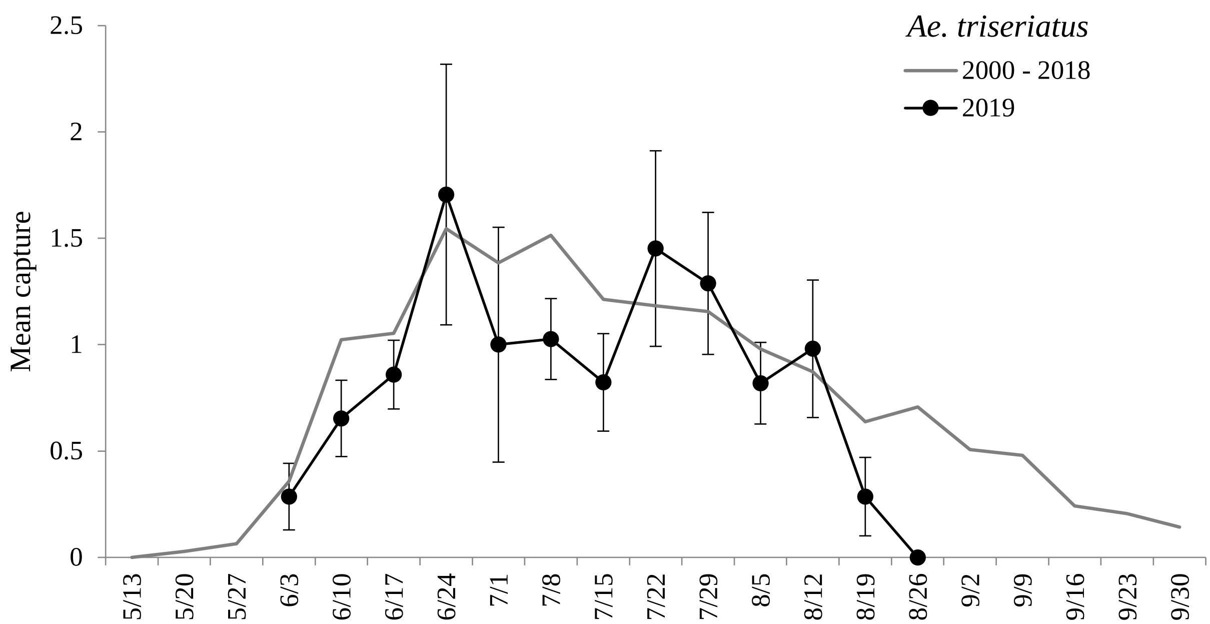


Figure 2.1 Mean number of *Ae. triseriatus* adults in 2019 aspirator samples plotted by week compared to mean captures for the corresponding weeks of 2000-2018. Dates listed are Monday of each week. Error bars equal ± 1 standard error of the mean.

La Crosse Encephalitis in Minnesota There were no LAC cases reported in Minnesota in 2019. 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 26 samples in 2019. All of the samples were collected from a tire recycling facility or adjacent properties in Scott County.

Specimens were reared from five ovitrap samples: one collected on July 11, one on August 23, and, three on September 25. Seven gravid trap samples contained *Ae. albopictus*; specimens were collected from June 19-October 2. One aspirator sample collected on August 23 contained *Ae. albopictus*. In 2019, BG Sentinel traps captured *Ae. albopictus* in the District for the first time. Thirteen BG Sentinel samples contained the species with collections occurring from June 26 to October 2. A total of 34 specimens were collected in the 21 samples that contained adult *Ae. albopictus*.

This was the seventeenth year and eighth 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.

Aedes japonicus larvae were found in 421 samples. Most were from containers (211) and tires (59). Larvae were found in other habitats as well, including stormwater structures/artificial ponds (80), catch basins (58), wetlands (12), 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. There has been a decline in that frequency each of the last two seasons (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 2019.

Aedes japonicus adults were identified in 372 samples. They were found in 143 aspirator samples, 99 gravid trap samples, 81 CO_2 trap samples, 26 two-minute sweep samples, 16 BG Sentinel trap samples and seven New Jersey trap samples. *Aedes japonicus* were also hatched from 16 of 50 ovitrap samples collected in 2019.

In 2019, the rate of capture of *Ae. japonicus* in aspirator samples remained near average until late July, when collections rose above average (Fig. 2.3). The peak rate of capture occurred during the week of August 12 at 0.9 *Ae. japonicus* per sample.

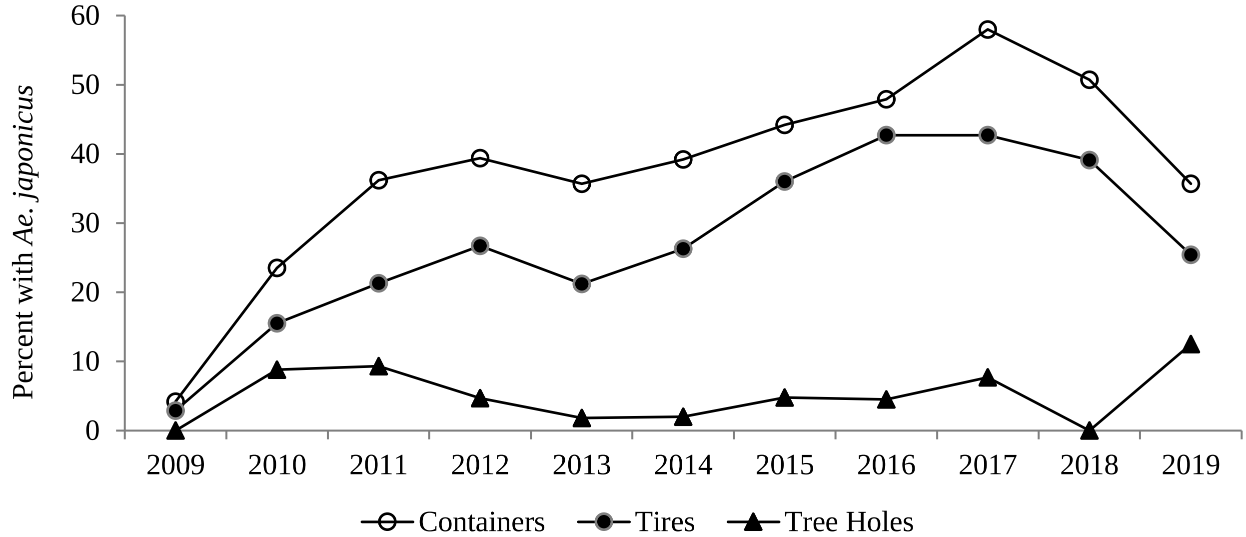


Figure 2.2 Percentage of larval samples from containers, tires, and tree holes containing *Ae. japonicus* by year.

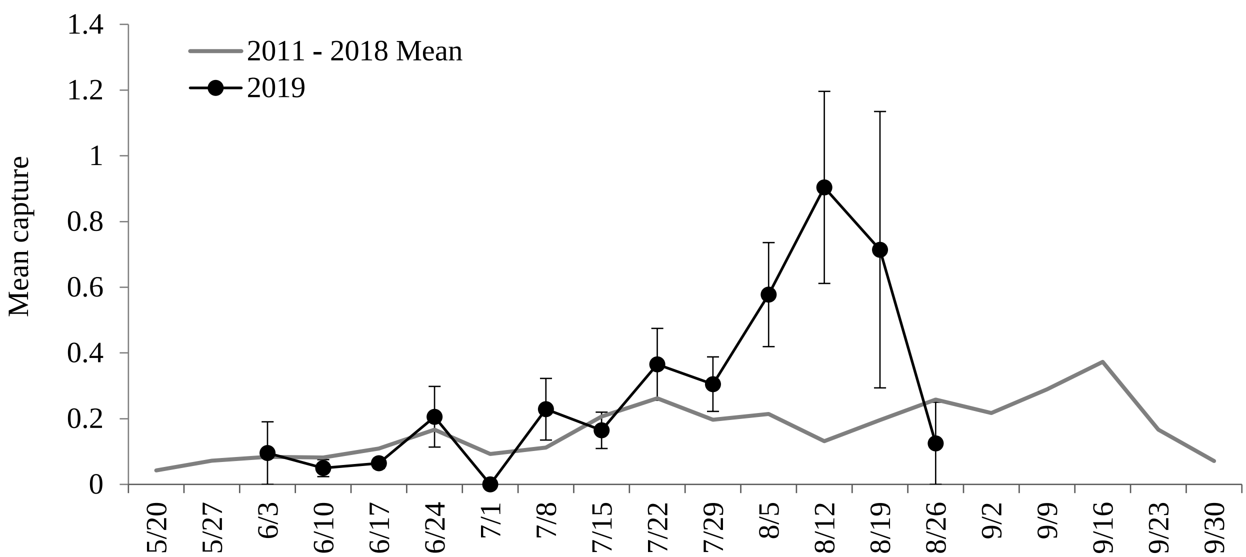


Figure 2.3 Mean number of *Ae. japonicus* adults in 2019 aspirator samples plotted by week compared to mean captures for the corresponding weeks of 2011-2018. Dates listed are Monday of each week. Error bars equal ± 1 standard error of the mean.

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 47 states in 2019. The U.S. Centers for Disease Control and Prevention received reports of 917 West Nile illnesses from 43 states and the District of Columbia. There were 51 fatalities attributed to WNV infections. California reported the greatest number of cases with 214. The states with the highest neuroinvasive disease incidence included Arizona, Nevada, and New Mexico. Nationwide screening of blood donors detected WNV in 100 individuals from 23 states.

WNV in Minnesota MDH reported three WNV illnesses in Minnesota residents from three counties. There were no WNV fatalities in Minnesota in 2019. There was one presumptively viremic blood donor reported from Minnesota. There were no reports of WNV illness in horses or other domestic animals in 2019. West Nile virus was detected in three loons found in St. Louis County.

WNV in the District There were two WNV illnesses reported in residents of the District, one in Dakota County and one in Hennepin County. Since WNV arrived in Minnesota, the District has experienced an average of 9.8 WNV illnesses each year (range 0-25, median 8). When cases with suspected exposure locations outside of the District are excluded, the mean is 7.8 cases per year (range 0-18, median 6).

Surveillance for WNV - Mosquitoes Surveillance for WNV in mosquitoes began during the week of May 20 and continued through the week of September 23. 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 649 mosquito pools using the RAMP® method, five 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, 2019. MIR is calculated by dividing the number of positive pools by the number of mosquitoes tested.

Species	Number of mosquitoes	Number of pools	WNV+ pools	MIR per 1,000
Cx. pipiens	37	2	0	0.00
Cx. restuans	1,239	50	0	0.00
Cx. salinarius	4	1	0	0.00
Cx. tarsalis	1,500	142	0	0.00
Cx. pipiens/Cx. restuans	3,073	202	2	0.65
Culex species	5,137	252	3	0.58
Total	10,990	649	5	0.45

The first WNV positive samples of 2019 were two pools of *Cx. pipiens/restuans* collected on August 7; a pool of five collected in St. Paul and a pool of 50 collected in Golden Valley. The three other WNV positive mosquito samples were all mixed pools of *Culex* species collected on August 14, September 5, and September 11. Three of the WNV positive samples were collected in Ramsey County and two were from Hennepin County. All five 2019 WNV positive samples were collected by gravid traps.

The WNV cycle was slow to begin in 2019. This was the fourth 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 2019 mosquito season, the virus was detected in only four of the 19 weeks of MMCD testing (Fig. 2.4). The minimum WNV infection rate in mosquitoes peaked during the second week of September at 5.59 per 1,000 mosquitoes tested.

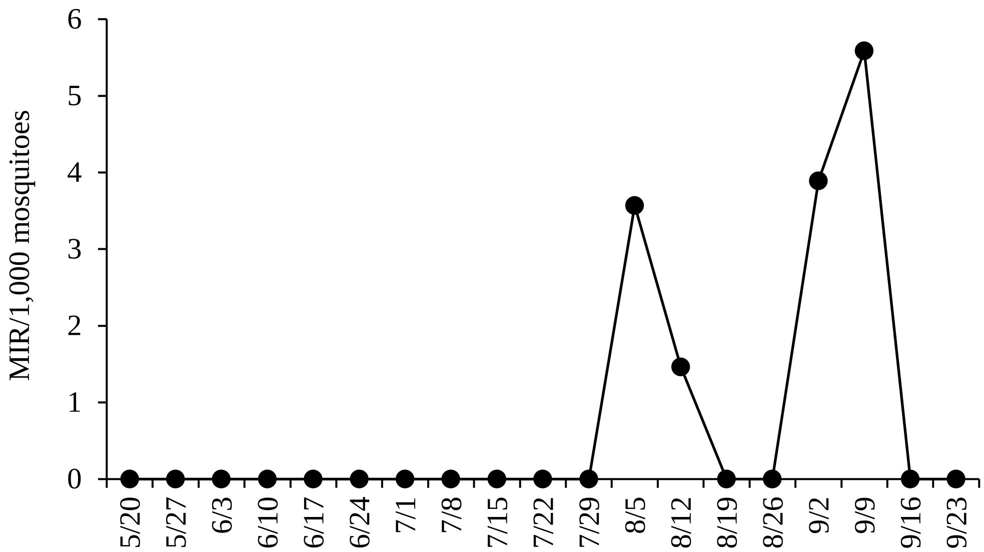


Figure 2.4 Weekly minimum WNV infection rates (MIR) per 1,000 *Culex* specimens tested in 2019. Dates listed are the Monday of each sampling week.

Surveillance for WNV - Birds The District received only 18 reports of dead birds by telephone, internet, or from employees in the field in 2019. Nine of 15 birds reported from May through October were corvids, seven were American crows and two were blue jays. All other reports were of non-corvids. No birds were tested by MMCD for WNV in 2019.

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 2019 season. Weekly mean collections peaked at 3.2 *Cx. tarsalis* per sample twice, on June 17 and July 15 (Fig. 2.5). As is typical, few *Cx. tarsalis* were captured by gravid trap in 2019.

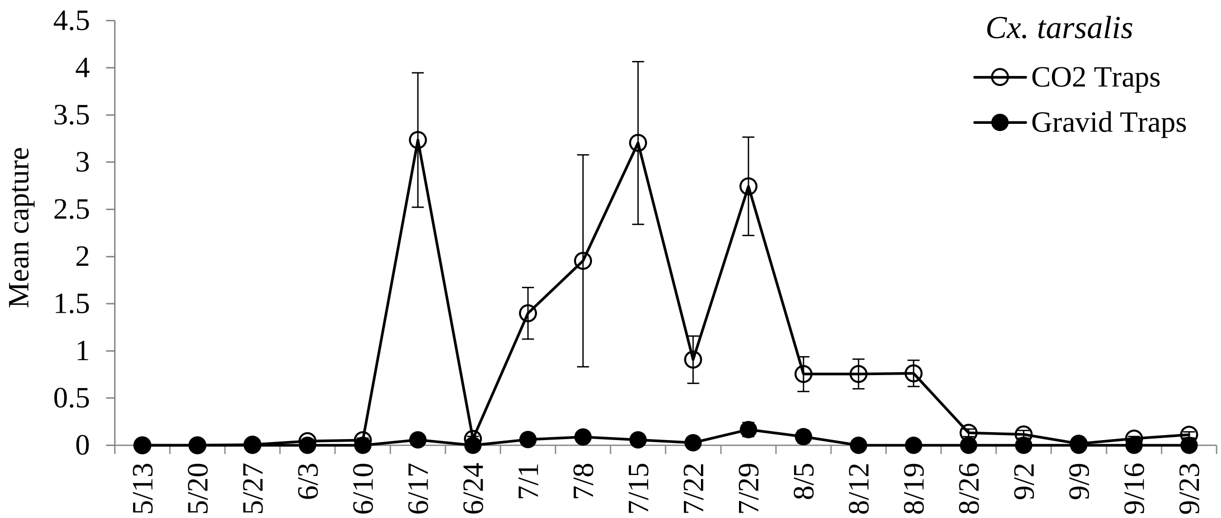


Figure 2.5 Average number of *Cx. tarsalis* in CO_2 traps and gravid traps, 2019. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

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 2019 (Fig. 2.6). The CO_2 trap captures peaked on June 10 at 2.2 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 24 at 15.1 per trap.

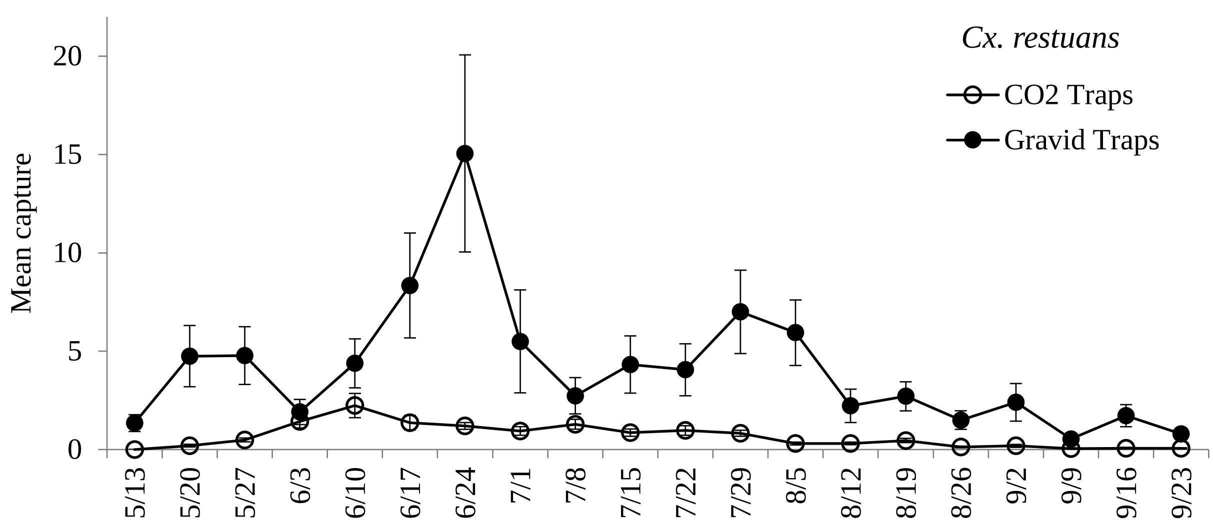


Figure 2.6 Average number of *Cx. restuans* in CO_2 traps and gravid traps, 2019. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

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 2019, collections of *Cx. pipiens* in both CO_2 traps and gravid traps were very low (Fig. 2.7). The rate of capture peaked at 1.4 per gravid trap during the week of September 23 and at 0.7 per CO_2 trap during the week of August 26.

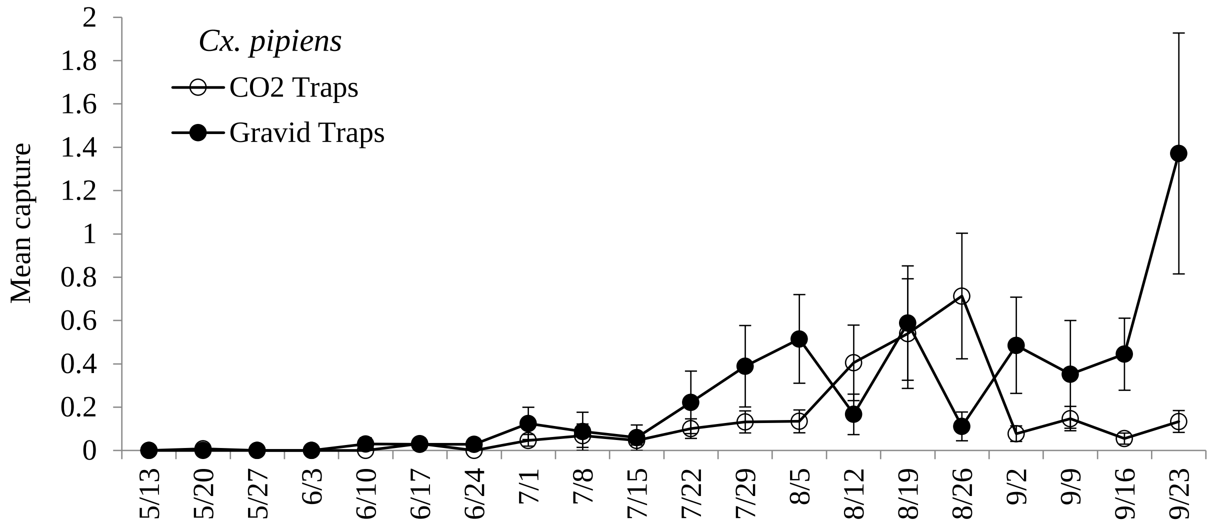


Figure 2.7 Average number of *Cx. pipiens* in CO_2 traps and gravid traps, 2019. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

Often, *Cx. pipiens* and *Cx. restuans* 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.

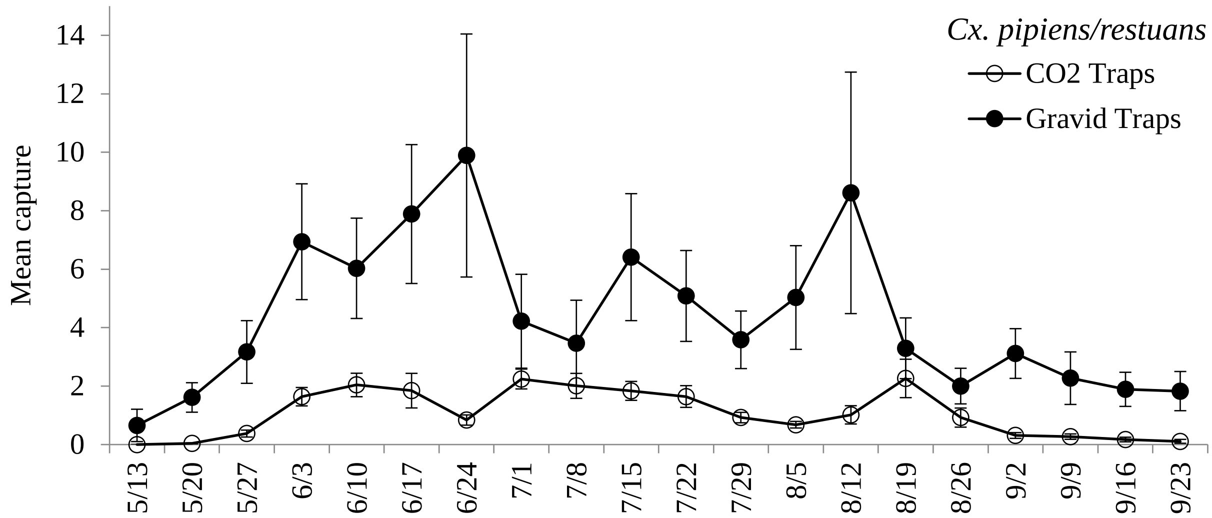


Figure 2.8 Average number of *Cx. pipiens/restuans* in CO_2 traps and gravid traps, 2019. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

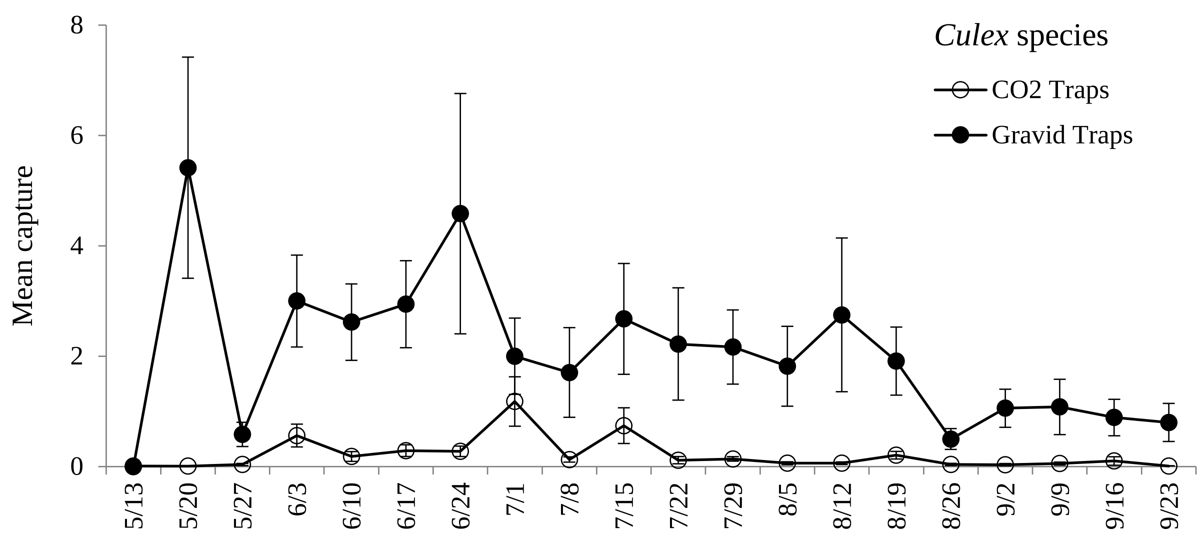


Figure 2.9 Average number of *Culex* species in CO_2 traps and gravid traps, 2019. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

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 664 larval samples from stormwater structures and other constructed habitats. *Culex* vectors were found in 79.7 percent of the samples in 2019 (Table 2.4). *Culex pipiens* were found less frequently (5.4 percent of samples) than in any other year dating back to 2006. This was only the third year of 14 seasons of surveillance in these habitats when fewer than ten percent of samples contained *Cx. pipiens* larvae (2008 – 8.1%, 2014 – 8.9%).

Table 2.4 Frequency of *Culex* vector species in samples collected from stormwater management structures and other constructed habitats from 2015-2019.

	Yearly percent occurrence				
Species	2015 (N=701)	2016 (N=625)	2017 (N=627)	2018 (N=765)	2019 (N=664)
Cx. pipiens	24.4	27.4	39.7	46.5	5.4
Cx. restuans	71.0	75.4	60.0	63.7	75.0
Cx. salinarius	0.4	0.0	0.5	0.0	0.0
Cx. tarsalis	2.4	3.5	3.2	1.4	3.2
Any *Culex* vector spp.	81.6	90.1	74.6	81.2	79.7

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

In 2019, we continued the cooperative mosquito control plan for underground habitats. Seventeen 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 928 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 2019; 928 structures were treated with a total of 1,046 briquets.

City	Structures treated	Briquets used	City	Structures treated	Briquets used
Bloomington	98	115	Minneapolis	170	170
Brooklyn Park	4	15	New Brighton	5	8
Columbia Heights	10	14	New Hope	39	50
Eden Prairie	12	20	Prior Lake	66	66
Edina	50	100	Richfield	13	25
Golden Valley	132	132	Roseville	27	29
Little Canada	3	3	Savage	56	56
Maplewood	225	225	Spring Lake Park	2	2
Mendota Heights	16	16			

Larval Surveillance in Catch Basins Catch basin larval surveillance began the week of May 20 and ended the week of September 23 (Fig. 2.10). Larvae were found during 392 of 544 catch basin inspections (72.1%) in 2019.

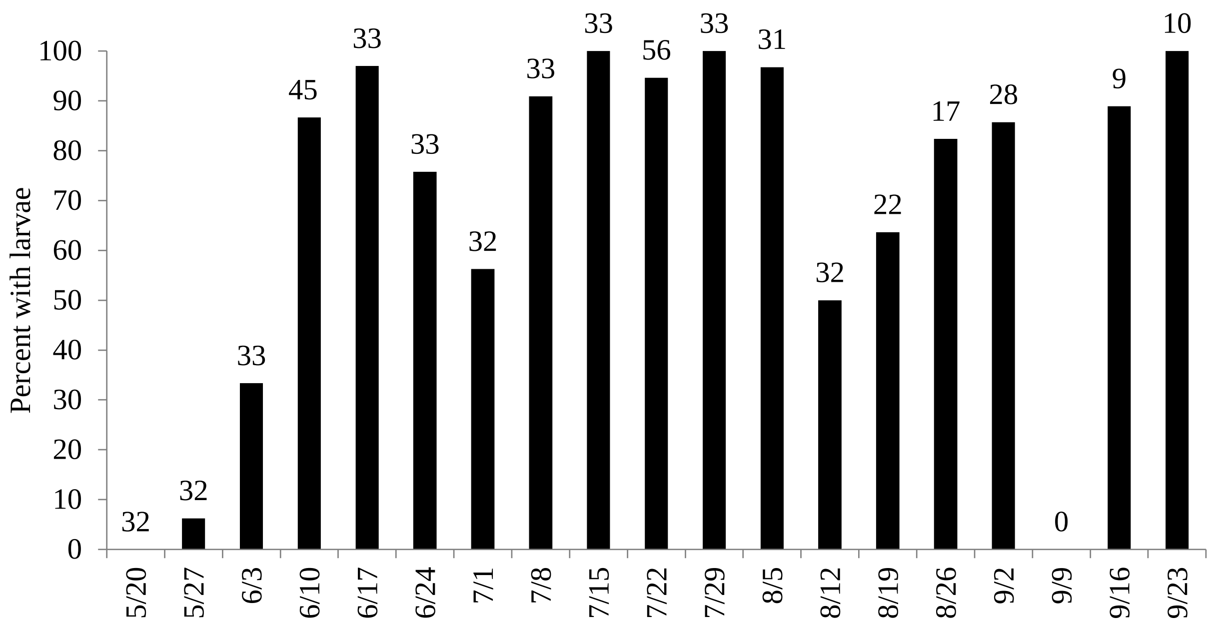


Figure 2.10 Percent of catch basins inspected with mosquitoes present in 2019. Bars are labeled with the number of inspections occurring during the week. Excludes surveillance of sites treated with the larvicide VectoLex FG.

Mosquito larvae were identified from 385 catch basin samples. *Culex restuans* were found in 83.1% of catch basin larval samples. *Culex pipiens* were found in 10.6% of samples. At least one *Culex* vector species was found in 96.1% of samples. *Culex restuans* were common in catch basins throughout the season (Fig. 2.11), while *Cx. pipiens* were collected less frequently than during most seasons.

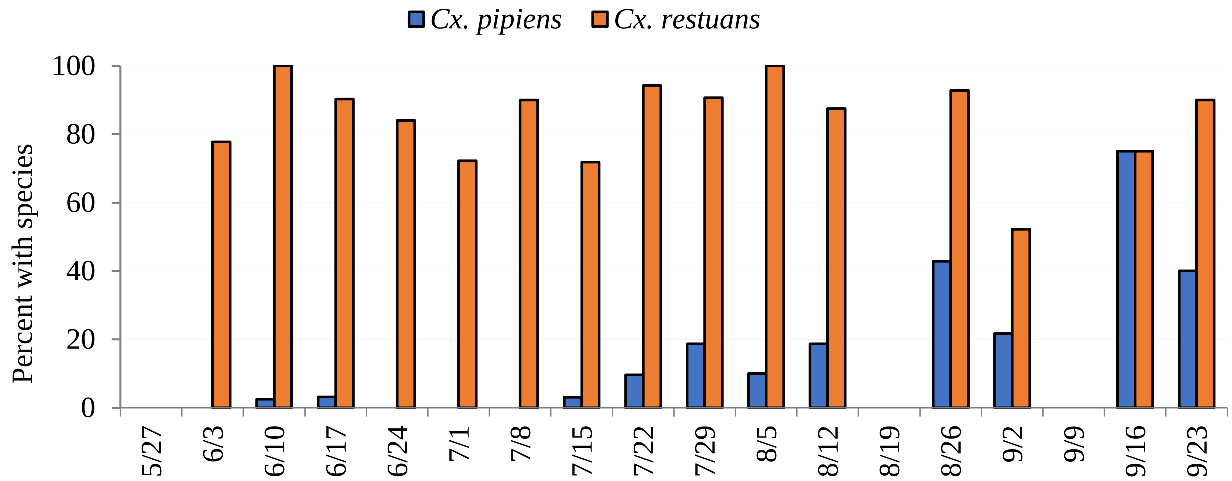


Figure 2.11 Percent occurrence of *Cx. pipiens* and *Cx. restuans* in catch basin larval samples by week. No sampling occurred the week of 8/19/2020.

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 2019, ten states reported a total of 38 human EEE illnesses. Fifteen of those illnesses were fatal. Massachusetts reported 12 illnesses and Michigan had 10. There were veterinary reports of EEE activity in 23 states. A total of 184 EEE illnesses in horses were reported. Eleven states reported EEE positive findings from mosquito samples.

Two of the equine EEE illnesses reported in 2019 occurred in Minnesota. Both horses were stabled on the same farm in northeast Otter Tail County. These were the first veterinary reports of EEE illness in Minnesota since 2012. Additionally, four ruffed grouse harvested by hunters in 2019 were positive for EEE, three in Itasca County and one in Aitkin County.

***Culiseta melanura* Surveillance** *Culiseta melanura*, the enzootic vectors of EEE, are relatively rare in the District and are usually restricted to a few bog-type larval habitats. The greatest concentration of this type of habitat is in the northeast part of MMCD in Anoka and Washington counties. Still, *Cs. melanura* specimens are occasionally collected in other areas of the District. Larvae are most frequently found in caverns in sphagnum moss. Overwintering is in the larval stage with adults emerging in late spring. There are multiple generations per year, and progeny of the late summer cohort become the next year’s first generation. Most adults disperse a short distance from their larval habitat, although a few may fly in excess of five miles from their larval habitat.

The *Cs. melanura* population remained low in 2019 with a season total of only 52 adult females collected in 229 CO_2 trap placements. Six pools containing 38 *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 June 3 (Fig. 2.12). The population remained low throughout the season with a maximum capture of 1.1 per trap on August 26.

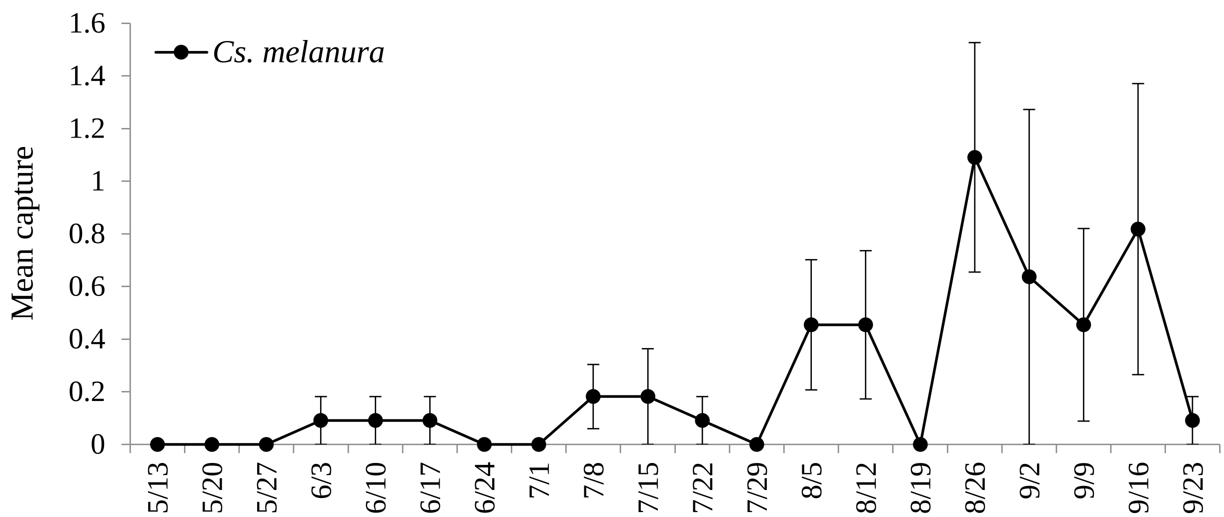


Figure 2.12 Mean number of *Cs. melanura* adults in CO_2 traps from selected sites, 2019. Dates listed are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

Staff collected 68 *Cs. melanura* in 39 aspirator samples from wooded areas near bog habitats. The first aspirator collections of *Cs. melanura* occurred during the week of June 17 (Fig. 2.13). The peak rate of capture was 3.6 *Cs. melanura* per sample during the week of August 12. *Culiseta melanura* develop primarily in bog habitats in the District, and larvae can be difficult to locate. In 2019, nine sites were surveyed for the species. *Culiseta melanura* larvae were found in six sites.

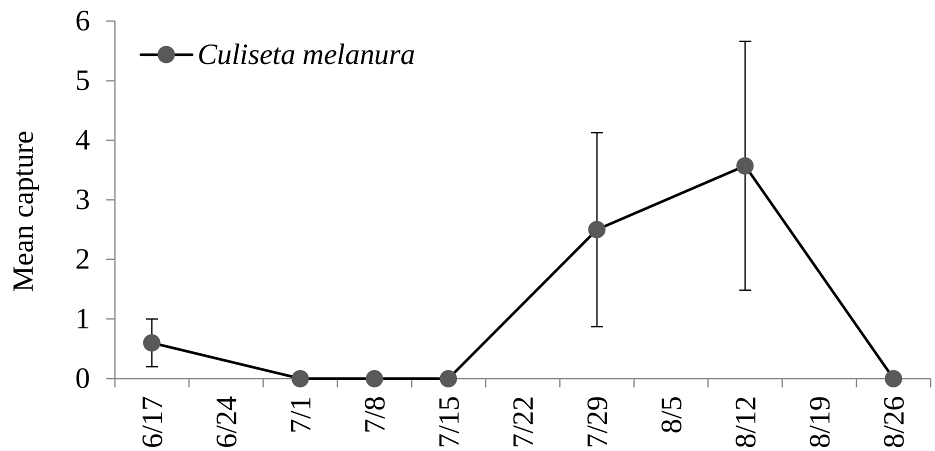


Figure 2.13 Mean number of *Cs. melanura* in 2019 aspirator samples plotted by week. Dates listed are Monday of each week. There were no samples during the weeks of June 24, July 22, August 5, and August 19. Error bars equal ± 1 standard error of the mean.

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 low in the District in 2019 (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.

MDH confirmed 13 JCV illnesses in Minnesota in 2019. Four cases were diagnosed in residents of the District (two in Hennepin Co. and two in Ramsey Co.). Nationally, there were 34 JCV illnesses reported. Wisconsin reported 14 of the illnesses.

MMCD partnered with the Midwest Center of Excellence for Vector-borne Disease (MCE-VBD) in 2018 to investigate JCV transmission in the region. Collections of *Ae. canadensis*, *Ae. cinereus*, and other spring *Aedes* species were pooled for JCV testing. Eighty-six pools of *Ae. canadensis*, 167 pools of *Ae. cinereus*, and 175 pools of mixed spring *Aedes* species were submitted to the MCE-VBD lab at the University of Wisconsin-Madison for testing. One pool containing three *Ae. provocans* collected on June 12, 2018 in Scandia was positive for JCV.

In 2019, we focused our JCV surveillance efforts in the vicinity of the 2018 JCV positive mosquito sample. We conducted early spring larval surveillance in several wetlands within a few hundred yards of the trap from which the positive sample was collected. Our goal was to collect *Ae. provocans* larvae to test for JCV in an effort to document transovarial transmission of the virus. We also added one CO_2 trap to our weekly network set approximately 500 meters east of the original JCV positive trap. Those two traps and the next two closest traps in the weekly network were processed for JCV analysis from the beginning of the season until early August. Additionally, several samples of *Aedes*, *Culiseta*, and *Anopheles* species were pooled for JCV testing from other CO_2 traps in the weekly network. Submissions for JCV analysis are summarized in Table 2.6.

There was one JCV positive result from the banded legged spring *Aedes* group. At the MCE-VBD lab, several of the submitted pools were combined for testing by species and date of collection to reduce expenses. The JCV positive sample was a combination of three pools collected on June 18 from three different Scandia CO_2 traps.

Table 2.6 Number of MMCD mosquito pools submitted for Jamestown Canyon virus analysis

Species	Number of Mosquitoes	Pools Submitted	Pools Tested	JCV+ Pools
Ae. canadensis	1125	76	76	0
Ae. spencerii	1	1	0	-
Ae. sticticus	208	25	25	0
Ae. provocans larvae	164	11	11	0
Ae. provocans adults	37	12	12	0
Ae. abserratus/punctor	1165	46	46	0
Banded legged spring *Aedes*	1173	48	48	1
An. punctipennis	144	54	54	0
An. quadrimaculatus	23	16	16	0
An. walkeri	692	88	0	-
Anopheles species	8	4	0	-
Cs. inornata	87	48	48	0
Total	4,827	429	336	1

2020 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

2019 Highlights

- Number of sites positive for *I. scapularis* was 62
- Average *I. scapularis* per mammal was 0.80
- *Amblyomma americanum* 1 report MMCD, 1 report MDH (both reports inside District boundaries)
- 2019 tick-borne cases not available; 2018 Lyme case total: 950 (17 cases per 100,000, source MDH)
- Anaplasmosis cases in 2018 totaled 496 (8.9 cases per 100,000, source MDH)
- MMCD created a lone star/Asian longhorned tick two-sided tick card
- 1st locally acquired Gulf Coast tick *(Amblyomma maculatum)* by MDH, Ramsey County

2020 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 *A. americanum* or other new or unusual tick species, including *H. 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 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 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 precautions. District employees continue to provide tick identifications upon request and are used as a tick referral resource by agencies such as the MDH and the Minnesota Department of Natural Resources (MNDNR).

2019 Tick-borne Disease Services

Lyme Disease and Human Anaplasmosis

Our tick surveillance began to detect increases in the metro *I. scapularis* population in 1998, with obvious expansion beginning in 2000. Since then, we have documented record-setting collection seasons on an ongoing basis. In parallel, but with a two-year lag (since 2000), the MDH has been documenting ongoing record-setting human tick-borne disease case totals. Pre-2000, the highest Lyme disease case total was 302 but since 2000 the Lyme disease totals have ranged from 463 to 1,431 cases, and now typically average >1,000 per year. Human anaplasmosis cases have also been on the rise. After averaging roughly 15 cases per year through 1999, the total HA case numbers ranged from 78 to 186 from 2000-2006 then increased into the range of the 300s. The all-time high, statewide Lyme disease case record (1,431) was set in 2013. The all-time high HA record of 788 was set in 2011. There were 950 Lyme disease and 496 HA cases in 2018, both lower than in 2017. Case totals from 2019 are not yet available.

Ixodes scapularis Distribution Study

The District continued to sample the network of 100 sites set up in 1991-1992 to monitor potential changes in tick distribution over time. As in previous years, the primary sampling method involved capturing small mammals from each site and removing any attached ticks from them. Collections from the northeastern metropolitan area (primarily Anoka and Washington counties) have consistently detected *I. scapularis* since 1990, and in 1998 *I. scapularis* was detected in Hennepin and Scott counties for the first time. We collected at least one *I. scapularis* from all seven counties that comprise our service area for the first time in 2007. Since then, we have detected *I. scapularis* with greater frequency, and they appear to be prevalent now in many wooded areas south of the Mississippi River. The 2019 Lyme Tick Distribution Study report will be available on our website in June (https://mmcd.org/publications/). Following are some preliminary 2019 highlights:

The average number of *I. scapularis* collected per mammal (0.80), excluding 2003 (0.389), 2006 (0.637), 2008 (0.644), and 2013 (0.401), is lower than all of our yearly averages from 2000-2018 (range 1.21-1.68), but it is higher than all of our averages tabulated from 1990-1999 (range 0.09-0.406) (Table 3.1). Our record high of 1.68 had been tabulated in 2016.

As has occurred in all years since 2007, except for 2011, we collected at least one *I. scapularis* from all seven counties that comprise our service area. From 2000-2009 our yearly positive site totals were typically in the 50s. The first time we had a site total of 70 or more was in 2010, then through 2014 our totals were either in the 50s or 70s. The first time we tabulated a site total of 80 or more was in 2015 when we had 81 positive sites, and our record high of 82 positive sites was set in 2016. We tabulated 62 positive sites in 2019. Maps are included in our yearly Lyme tick distribution study.

Table 3.1 Yearly totals of the number of mammals trapped and ticks collected (by tick species and life stage), and the average number of *I. scapularis* per mammal, 1990-2019. The number of sites sampled was 250 in 1990, 270 in 1991, 200 in 1992, and 100 from 1993 to present.

			Dermacentor variabilis		*Ixodes scapularis*			
Year	No. mammals	Total ticks collected	No. larvae	No. nymphs	No. larvae	No. nymphs	No. other species[b]	Ave. *I. scap* / mammal
1990 [a]	3651	9957	8289	994	573	74	27	0.18
1991	5566	8452	6807	1094	441	73	37	0.09
1992	2544	4130	3259	703	114	34	20	0.06
1993	1543	1785	1136	221	388	21	19	0.27
1994	1672	1514	797	163	476	67	11	0.33
1995	1406	1196	650	232	258	48	8	0.22
1996	791	724	466	146	82	20	10	0.13
1997	728	693	506	66	96	22	3	0.16
1998	1246	1389	779	100	439	67	4	0.41
1999	1627	1594	820	128	570	64	12	0.39
2000	1173	2207	1030	228	688	257	4	0.81
2001	897	1957	1054	159	697	44	3	0.83
2002	1236	2185	797	280	922	177	9	0.89
2003	1226	1293	676	139	337	140	1	0.38
2004	1152	1773	653	136	901	75	8	0.85
2005	965	1974	708	120	1054	85	7	1.18
2006	1241	1353	411	140	733	58	11	0.59
2007	849	1700	807	136	566	178	13	0.88
2008	702	1005	485	61	340	112	7	0.64
2009	941	1897	916	170	747	61	3	0.86
2010	1320	1553	330	101	1009	107	6	0.85
2011	756	938	373	97	261	205	2	0.62
2012	1537	2223	547	211	1321	139	5	0.95
2013	596	370	88	42	147	92	1	0.40
2014	1396	2427	580	149	1620	74	4	1.21
2015	1195	2217	390	91	1442	291	3	1.45
2016	1374	3038	576	153	2055	252	2	1.68
2017	1079	1609	243	45	1101	204	6	1.21
2018	765	1439	219	68	1007	139	6	1.50
2019	1121	1164	280	54	645	181	4	0.80

[a] 1990 data excludes one *Tamias striatus* with 102 *I. scapularis* larvae and 31 nymphs

[b] other species mostly *Ixodes muris.* 1999—second adult *I. muris* collected

Tick-borne Disease Prevention Services

Identification Services and Outreach The overall scope of tick-borne disease education activities and services were maintained in 2019 and included tick identifications and homeowner consultations, updating our Tick Risk Meter on our website, and providing tick-borne disease information on MMCD's Facebook page and at the Minnesota State Fair and county fairs in the seven-county metropolitan area. 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 were dropped off at roughly 270 locations (e.g., city halls, libraries, schools, child care centers, retail establishments, vet clinics, parks) across the metro as well as distributed at fair booths and city events, with many more mailed upon request.

Additional Updates – 2019

First Locally Acquired Gulf Coast Tick (*Amblyomma maculatum*) The MDH reported Minnesota's first known locally acquired *A. maculatum*, an adult female. It was found on a person on August 8, 2019 in Ramsey County. Of note, a former MDH employee had also found an *A. maculatum* female in 2019, in northwest Iowa on a dog. While of interest, we presume these records were transient introductions into our area as the range of the Gulf Coast tick now extends into both southern Kansas and southern Missouri.

Asian Longhorned Tick (*Haemaphysalis longicornis)* US Introduction The Asian longhorned tick (*H. longicornus*) was first detected on a sheep in New Jersey in the fall of 2017. Further research has determined this tick to have been present in the United States since at least 2010. It has been found mostly on the Eastern Seaboard but has also been found in Arkansas. While its principle host is cattle, it will feed on a variety of mammal species. It has the potential to feed on humans as well. *Haemaphysalis longicornis* spreads many different bacterial, protozoan, and viral diseases in other countries, most of which are in the same genus as our tick-borne diseases that are native to the United States.

Depending on type, *H. longicornis* can reproduce sexually, asexually, or using both methods. 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.

The "good news" for Minnesota is that there is some question as to survivability in low or high temperatures. The lowest temperatures this parthenogenetic type of Asian longhorned tick is known to be able to withstand is 14°F. Whether it can survive in lower temperatures is unknown. Temperatures in the range of 81°F - 86°F and higher are detrimental to egg development of the parthogenetic type of *H. longicornis*.

MMCD is preparing for possible *H. longicornis* introductions into Minnesota, in part, by participating in an inter-agency collaboration. Staff from the Minnesota Board of Animal Health and the MDH convened an inter-agency meeting early in 2019 to update all on the materials and procedures they had in place and to solicit ideas and ways we could all collaborate on our efforts, enhance outreach, and plan for the possibility of a Minnesota introduction of the Asian longhorned tick. 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

All agencies will 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 – Specific Plans MMCD is in a good position to detect introductions of *H. longicornus* in our service area.

- Staff were educated on *H. longicornus* identification and instructed to turn in any unusual looking adult ticks for identification.
- Our tick identification service has been in place for many years. We continued to encourage the public to turn in ticks for identification.
- Since *H. longicornis* immatures are now 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 created and distributed an Asian longhorned tick identification card (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 utilized Facebook to keep the public informed of *H. longicornis* updates and to enlist their help in watching for this tick.

There were no reports of *H. longicornis* detected in Minnesota in 2019, and there were no new states added to the list of states where *H. longicornis* has been found.

Amblyomma americanum **(Lone Star Tick)** *Amblyomma americanum* is an aggressive human biter and can transmit bacteria that cause human monocytic ehrlichiosis (HME), among other potential pathogens. Both the tick and HME are more common to the southern U.S., but the range of *A. americanum* is known to be moving northward. *Amblyomma americanum* ticks have been submitted to MMCD from the public on a rare, sporadic basis, and this species was first collected by MMCD in 1991 via a road-kill examination of a white-tailed deer (*Odocoileus virginianus*). However, in 2009, for the first time in a number of years, the public submitted *A. americanum* to both MDH and MMCD (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.

In 2017, MMCD did not receive any reports but MDH received one report each from Hennepin and Washington counties as well as three additional reports from outside MMCD's service boundaries. In 2018, MDH received a report of one adult (sex unknown), and they also collected one adult female in Itasca State Park, outside MMCD's service boundaries. MMCD received one adult female *A. americanum* from Shoreview (Ramsey County). In 2019, there were two *A. americanum* collected. MMCD collected one adult female in Scott County, and MDH reported one adult female from Washington or Hennepin counties. Including these 2019 submissions, between our two agencies we have totaled 34 *A. americanum* collected since 2009.

2020 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, which include tick identifications, homeowner consultations, updating the Tick Risk Meter on our website, using social media, 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 continue 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

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

Asian Longhorned Tick (*Haemaphysalis longicornus*), 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

2019 Highlights

- In 2019, 24,396 more acres were treated with larvicide (213,587 acres) than in 2018 (189,191 acres)
- 34,864 acres worth of potential larval treatments were not applied to reduce expenditures
- A cumulative total of 266,391 catch basin treatments were made in three rounds to control WNV vectors
- In 2019, 16,158 fewer acres of adulticide treatments were made (22,321 acres) than in 2018 (38,479 acres)
- P35, a new granular Altosid® formulation, was uniformly applied at 3 lb/acre by helicopters in tests. Altosid® P35 can be used to treat 33% more area than Altosid® pellets (4 lb/acre)

2020 Plans

- Replace about one third of the larval control cut in 2017 as part of the expenditure reduction steps
- Substitute Altosid® P35 for Altosid® pellets for cattail treatments
- Explore substituting Altosid® P35 for Altosid® pellets for prehatch treatments
- Continue spring *Aedes* larval surveillance in areas with high adult abundance to target potential Jamestown Canyon vectors
- Work closely with MPCA to fulfill the requirements of a NPDES permit

Background

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

Due to the large size of the metropolitan region (2,975 square miles), larval control was considered the most cost-effective control strategy in 1958 and remains so today. Consequently, larval control is the focus of the control program and the most prolific mosquito habitats (81,639 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).

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 2019: 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.

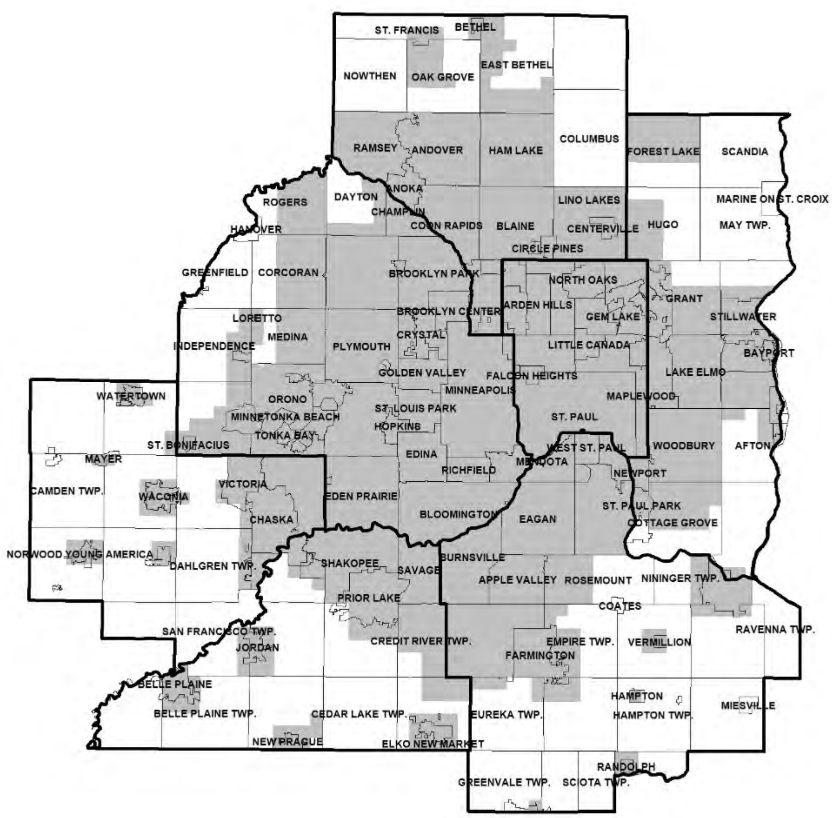


Figure 4.1 Priority zones 1 (shaded-P1) and 2 (white-P2), with District county and city/township boundaries, 2019.

2019 Mosquito Control

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 4.1 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.

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 (*Bs. 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) 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 2019 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 4.1), 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 4.1). The *Culex*4 (four vector species) threshold is 2 in both priority zones (Table 4.1). If *Aedes* and *Culex* vectors are both present in a site and neither meet their threshold, the site can be treated if the combined count meets the summer *Aedes* threshold.

Table 4.1 Air site larval thresholds by priority zone and species group in 2019

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

[a] Summer = Summer *Aedes* or *Aedes* + *Culex* 4

[b] *Culex* 4 = *Cx. restuans, Cx. pipiens, Cx. salinarius, Cx. tarsalis*

Some sites 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 prehatch treatments (Natular® G30, Altosid® pellets, MetaLarv® S-PT) were applied in mid-May with a second in mid-June and a third in mid-July.

Temporary Program Changes in Response to Budget Resource Limitations The three-year period of 2014-2016 had record high rainfall and MMCD chose to spend $5.8 million from reserves to meet the unusual service needs. Since then, a combination of modest levy increases (1-3%) and spending reductions has been implemented to restore the needed reserves. More moderate weather conditions in 2017-2019 have also helped. The following are spending reduction steps started in 2017 and continued through 2019:

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

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

We estimate the four expenditure reduction steps involving larval control resulted in a reduction in larval treatments of 34,864 acres (Table 4.2). While significant, these temporary reductions did not represent a major larval control strategy change. As in previous years, the majority of larval control was conducted in P1. The District continued to provide some services to all citizens in the entire service area. Evaluation of the effect of these changes on adult mosquito numbers is found later in this chapter.

Table 4.2 Treatment reductions in 2019, the percent change pre-implementation of the expenditure reduction strategy in 2016, and the cost savings realized ($1,144,626 out of total savings of $1,499,695)

Type of treatment	Acres not treated	Percent change (from 2016 acres)	Savings
Bti treatments	8,551	-3.6	$130,328
Cattail treatments all larvicides	8,838	-23.3	$586,664
Partial/perimeter site treatments (*Bti*)	9,535	-4.1	$136,590
Pre-hatch treatment all larvicides	7,940	-21.9*	$291,044

* Percent change based on cost, not acres treated, because of shifting pre-hatch from air to ground and cattail treatments in 2019.

Spring *Aedes* Control Strategy In 2019, we continued expanded larval spring *Aedes* surveillance into P2 areas with higher past adult abundance (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 2019, we maintained the P1 spring *Aedes* larval threshold raised in 2018 from 0.5 to 1.0 larva per dip (Table 4.1) to treat sites that contained higher concentrations of larvae (in both P1 and P2). In 2019, we treated more acres for spring *Aedes* than in 2017 and 2018. Treatments in P2 in 2019 were greater than 2017 but less than in 2018 (Table 4.3). Adult spring *Aedes* abundance in 2019 remained relatively low (Table 1.2, 1.3).

Table 4.3 Aerial *Bti* treatment-acres to control spring *Aedes* in P1 and P2 in 2017, 2018, and 2019

	Acres treated		
Priority area	2017	2018	2019
P1	26,204.57	18,044.52	31,146.39
P2	11.86	2,785.85	874.58
Total	26,216.43	20,830.37	32,020.97

Season Overview As described in Chapter 1, we experienced a delay to the start of the mosquito season due to unseasonably cold conditions in March and April, culminating with significant snow on April 10-12. Staff detected the first spring *Aedes* larvae on April 5, 19 days earlier than in 2018 (April 24). Aerial *Bti* treatments to control the spring *Aedes* brood began on May 2, eight 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 20. In addition to the spring *Aedes* brood, there were three large and ten small-medium broods of *Ae. vexans* (a typical season has four large broods).

Aerial pre-hatch treatments (Natular® G30, Altosid® pellets) to control floodwater *Aedes* were applied in late May and late June. The majority of aerial treatments to control cattail mosquitoes using MetaLarv® S-PT and Altosid® pellets were applied the last ten days of May (Figure 4.2) and the first week of June; VectoLex® FG was applied on September 10-14 to control the overwintering larval population.

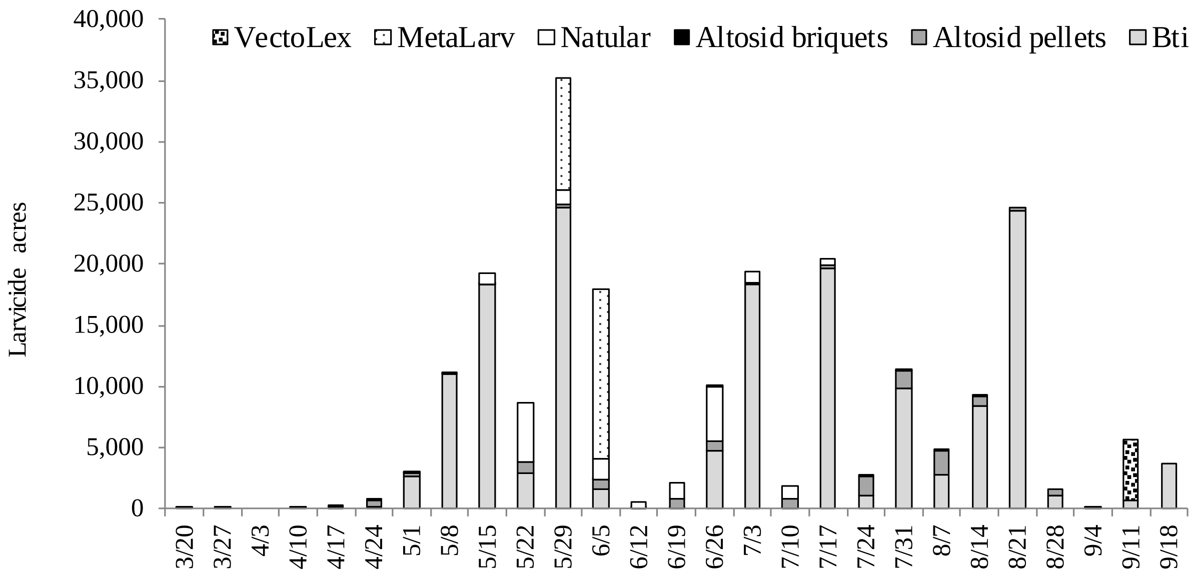


Figure 4.2 Acres treated with larvicide each week (March-September 2019). Date represents start date of week.

Table 4.4 Comparison of larval control material usage in wetlands, stormwater structures (other than catch basins) and containers, and in stormwater catch basins for 2018 and 2019 (research tests not included)

	2019		2018	
Habitat and material used	Amount used	Acres treated	Amount used	Acres treated
Wetlands and structures				
Altosid® briquets (cases)	222.81	162	236.70	167
Altosid® pellets (lb)	33,706.80	12,020	38,602.46	10,202
MetaLarv® S-PT (lb)	67,945.30	23,003	66,963.84	23,574
Natular® G30 (lb)	87,603.72	17,276	97,581.81	15,662
VectoLex® FG (lb)	72,037.95	5,036	71,834.65	4,660
VectoBac® G (lb)	880,675.13	155,735	755,355.86	134,926
Total wetland and structures		213,232		189,191
	Amount used	No. CB treatments	Amount used	No. CB treatments
Catch basins				
Altosid® briquets (cases)	2.16	476	2.31	509
Altosid® pellets (lb)	2,098.52	265,915	2,066.86	262,851
Total catch basin treatments		266,391		263,360

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

Cattail Mosquito Control Reduction Evaluation In 2018 and 2019, some control materials were shifted to cattail treatments to maximize treatment in P1 and restore very limited treatments in P2. Cattail mosquito larvicide treatments in P2 largely were not applied in 2017 as part of a strategy to reduce expenditures. Very limited treatments were applied in 2018 and 2019. 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.

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

We compared adult cattail mosquito abundance in groups of CO_2 traps in P1 (cattail larvicide treatments maintained in 2016-2019) and P2 (limited cattail larvicide treatments completed in 2016, largely curtailed in 2017-2019) in Washington and Hennepin counties (Figure 4.3). Abundance in traps located in Linwood Township in Anoka County (no cattail mosquito control in 2016-2019) served as a reference (Figure 4.3).

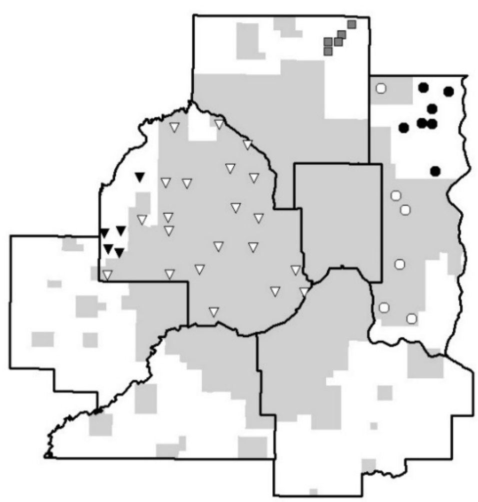


Figure 4.3 Location of CO_2 traps in Hennepin County (P1 white triangles, P2 black triangles), Washington County (P1 white circles, P2 black circles), and Anoka County (Linwood Township) (gray squares). P1 is shaded light gray.

Adult *Cq. perturbans* abundance as measured by CO_2 trap captures in 2016-2019 documented a large increase in 2017 throughout the District; abundance decreased in all five areas in 2018 compared to 2017 (Table 4.5). In 2019, abundance remained similar to 2018 except in P2 in Washington County where abundance increased (Table 4.5). In 2016, 2017, 2018, and 2019, abundance was lower in P1 than in P2 in Hennepin and Washington counties (Table 4.5) suggesting that larval control is lowering adult *Cq. perturbans* abundance in P1.

Table 4.5 Adult *Coquillettidia perturbans* mean abundance in Monday Night Network CO_2 trap collections in 2016, 2017, 2018 and 2019 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

The relative change in adult *Cq. perturbans* abundance each year was very similar in P1 and P2 of the District suggesting that environment (high precipitation in 2014, 2015, and 2016, lower precipitation in 2017 and 2018) resulted in similar relative changes of *Cq. perturbans* abundance in 2017, 2018, and 2019 throughout the observation area. The environmental impact seems to have been much stronger than potential effects of minimal larval control in P2. In 2016, 2017, 2018, and 2019, 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.

Coquillettidia perturbans predictions for 2020 (Chapter 1: Surveillance) suggest greater abundance of this species as compared to 2019. Thus, we expect to treat more acres in 2020 compared to 2019, especially in P1.

Spring *Aedes* Control Strategy Evaluation The five groups of CO_2 traps used to compare *Cq. perturbans* abundance also were used to compare spring *Aedes* abundance relative to treatments in 2016, 2017, 2018, and 2019. Hennepin P1 and Washington P1 are areas where aerial *Bti* treatments targeting spring *Aedes* were completed from 2016-2019. Aerial *Bti* treatments were conducted in Hennepin County P2 in 2016; these treatments were not made in 2017 and limited treatments were completed in 2018 and 2019. No significant aerial *Bti* treatments targeting spring *Aedes* were completed in 2016 and 2017 in Washington P2; very limited treatments were completed in 2018 and 2019. No significant aerial *Bti* treatments targeting spring *Aedes* were completed from 2016-2019 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 4.6). Spring *Aedes* abundance in 2016, 2017, and 2018 in P1 (Hennepin and Washington counties) was essentially equal for all three years; mean abundance each year differed by less than yearly variability (1 SE) (Table 4.6). Spring *Aedes* abundance was higher in 2019 in P1 (Hennepin and Washington counties) but still within variability limits (Table 4.6). Spring *Aedes* abundance in 2016 and 2017 in Hennepin P2 was essentially equal; mean abundance each year differed by less than yearly variability (1 SE) (Table 4.6). The same was true for P2 Washington County, although abundance in P2 Washington County appeared higher than P2 Hennepin County in 2017. Abundance in P2 appeared higher in 2019 than in 2016 and 2017, especially in Washington Co., although variance also was much higher in 2019. Spring *Aedes* abundance in Linwood Township increased each year through 2018 and was higher each year than in Hennepin and Washington counties (Table 4.6). The lack of spring *Aedes* increase in Hennepin County P2 in 2017 suggests that factors other than aerial *Bti* treatments contributed to the spring *Aedes* increase observed in Washington Co. P2 and Linwood Township.

Table 4.6 Adult spring *Aedes* mean abundance in Monday Night Surveillance CO_2 trap collections in 2016, 2017, 2018, and 2019 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		P2		P1		P2		P2	
Year	(n=21)		(n=5)		(n=6)		(n=7)		(n=5)	
2016	0.8 (±0.5)	F	3.7 (±1.8)	S	0.9 (±0.3)	F	2.6 (±0.9)	N	6.1 (±0.6)	N
2017	1.0 (±0.8)	F	1.5 (±0.8)	N	0.4 (±0.2)	F	8.5 (±5.5)	N	17.6 (±4.9)	N
2018	1.2 (±0.7)	F	7.6 (±3.0)	L	1.6 (±0.6)	F	22.3 (±9.6)	L	37.2 (±10.6)	N
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

Adult Mosquito Control

Thresholds Adult mosquito control operations are considered when mosquito levels rise above established thresholds for nuisance (*Aedes* spp. and *Cq. perturbans*) and vector species (Table 4.7). Staff conducted a study in the early 1990s that measured peoples' perception of annoyance while simultaneously sampling the mosquito population (Read et al. 1994). Results of this study are the basis of MMCD's nuisance mosquito thresholds. The lower thresholds for vector species are designed to interrupt the vector/virus transmission cycle. The sampling method used is targeted to specific mosquito species.

Table 4.7 Threshold levels by sampling method for important nuisance and vector species detected in MMCD surveillance. *Aedes* spp. and *Cq. perturbans* are considered nuisance mosquitoes; all other species 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 2019, adult mosquito levels rose in late June through mid-July; at those times, counts over threshold were fairly widespread (Figure 4.4). In 2019, MMCD applied 16,158 fewer acres worth of adulticides than in 2018 (Table 4.8, Appendix E). Figure 4.4 shows weekly adulticide acres treated (line). Adulticiding steadily increased in response to widespread spring *Aedes* and *Ae. vexans* emergence in mid-June and increasing numbers of *Culex* (WNV vectors) and the annual *Cq. perturbans* emergence continuing into the second week of July after which it decreased in late August. A greater proportion of adulticide treatments later in the summer targeted vector mosquitoes.

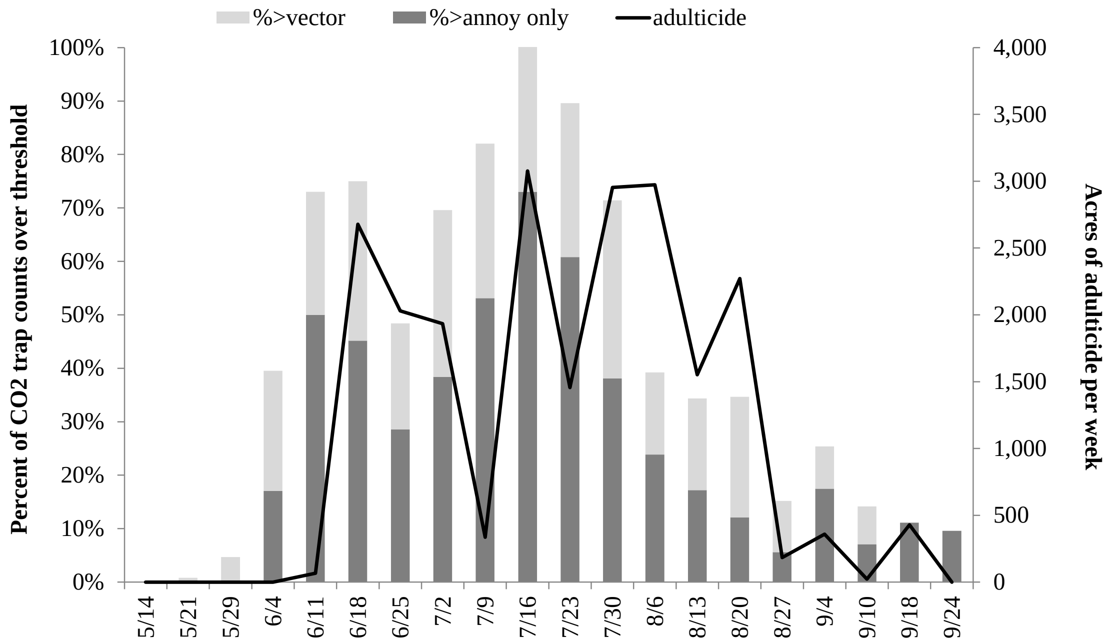


Figure 4.4 Percent of Monday CO_2 trap locations with counts over threshold compared with acres of adulticides applied in 2019 (solid line). Dark bars indicate the percentage of traps meeting annoyance mosquito thresholds and lighter bars represent the percentage of traps meeting the vector thresholds (*Culex*4, *Ae. triseriatus*, *Ae. japonicus*, *Cs. melanura*) on each sampling date. Date is day of CO_2 trap pick up.

Table 4.8 Comparison of adult control material usage in 2018 and 2019

	2019		2018	
Material	Gallons used	Acres treated	Gallons used	Acres treated
Permethrin	596.40	3,367	668.47	3,771
Sumithrin*	92.12	3,665	191.07	7,790
Etofenprox*	183.73	15,289	295.10	26,918
Total		22,321		38,479

* Products labeled for use in agricultural areas

References

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

2020 Plans for Mosquito Control Services

Integrated Mosquito Management Program

In 2020, 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 replacing 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 2020 will remain the same as in 2019.

Larval Control

Temporary Measures to Decrease Expenditures In 2020, we plan to scale back, by approximately one third, the five expenditure reduction steps first implemented in 2017. Because of an overall increase of acreage meeting larval threshold for the cattail mosquito treatment observed by larval surveillance District-wide in late 2019, we plan to allocate more resources for cattail mosquito control in 2020. We plan to replace all aerial and ground cattail treatments that used Altosid® pellets in 2019 with Altosid® P35 in 2020 because the 3 lb/acre treatment rate possible with Altosid® P35 will enable us to treat 33% more acreage with Altosid® P35 than with Altosid® pellets, which must be applied aerially at 4 lb/acre to achieve uniform treatments.

Floodwater Mosquitoes The primary control material will again be *Bti* corn cob granules. Larvicide needs in 2020, mainly *Bti* (VectoBac® G), Altosid® pellets, Altosid® P35, Natular® G30, and MetaLarv® S-PT, are expected to be similar to the five-year average larvicide usage (266,222 acres). In 2020, we plan to continue the spring *Aedes* larval threshold used in 2018 and 2019 (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 8 lb/acre and decrease the *Bti* dosage to 5 lb/acre when we switch to the summer *Aedes* threshold. As in previous years, to minimize shortfalls, control material use may be more strictly apportioned during the second half of the season, depending upon the amount of the season remaining and control material supplies. Regardless of annoyance levels, MMCD will maintain sufficient resources to protect the public from potential disease risk.

Staff will treat ground sites with Natular® G30, methoprene products (Altosid® pellets, Altosid® P35, Altosid® briquets, MetaLarv® S-PT), or *Bti* corncob granules. During a wide-scale mosquito brood, sites in highly populated areas will receive treatments first. The District will then expand treatments into less populated areas where treatment thresholds are higher. We will continue with the larval treatment thresholds used in 2019 (Table 4.1).

Each year staff review ground site histories to identify those sites that produce mosquitoes most often. This helps us to better prioritize sites to inspect before treatment, sites to pre-treat with Natular® G30 or methoprene products before flooding and egg hatch, and sites not to visit at all. The ultimate aim is to provide larval control services to a larger part of the District by focusing on the most prolific mosquito production sites.

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

Ground and aerial larvicide treatments of wetlands have been increased to control *Culex* species. Catch basin treatments control *Cx. restuans* and *Cx. pipiens* in urban areas. Most catch basins will be treated with Altosid® pellets or 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 pellet/P35 treatments by June 25 with subsequent Altosid® pellet/P35 treatments every 30 days thereafter.

Cattail Mosquitoes In 2020, control of *Cq. perturbans* will use a strategy similar to that employed in 2019. 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 2020 are expected to be similar to the five-year average adulticide usage (50,261 acres). We will continue to focus efforts where there is potential disease risk, as well as provide service in high-use park and recreation areas and for public functions and respond to areas where high mosquito numbers are affecting citizens.

Additional plans are:

- to use Anvil® (sumithrin) and Zenivex® (etofenprox) as needed to respond to elevated levels of adult mosquitoes as needed;
- to use Anvil® and Zenivex® as needed to control WNV vectors in agricultural areas because current labels now allow applications in these areas;
- to evaluate possible adulticide use in response to *Ae. japonicus* and *Cs. melanura*; and
- 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

2019 Highlights

- Treated 27 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 41 *Bti* treatments on the large rivers when the larval population of the three target species met the treatment threshold; a total of 4362.1 gallons of *Bti* was used for these treatments
- The start of *Bti* treatments on the Minnesota River were delayed until mid-June due to flood-level flows; this resulted in record high adult populations in parts of the District
- Monitored adult populations using overhead net sweeps and CO_2 traps; the average black fly/overhead sweep was 1.8
- Submitted non-target monitoring report to the MNDNR for samples collected on the Mississippi River in 2017

2020 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
- Process Mississippi River non-target monitoring samples

Background

The goal of the black fly control program is to reduce pest populations of adult black flies within the MMCD to tolerable levels. Black flies develop in clean flowing rivers and streams. Larval populations are monitored at 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.

2019 Program

Small Stream Program: *Simulium venustum* Control

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

Sampling to monitor larval populations of *S. venustum* for treatment thresholds in the MNDNR-permitted small streams was conducted between late-April and mid-May. A total of 191 monitoring samples were collected using MMCD's standard sampling technique. Twenty-seven sites on 10 streams met the treatment threshold of 100 *S. venustum* per sample that was established in 1990. These sites were treated once with VectoBac® 12AS *Bti*. A total of 43.1 gallons of VectoBac was used for the treatments (Table 5.1). In comparison, the average amount of *Bti* used to treat small stream sites annually during 1996-2018 was 27.1 gallons.

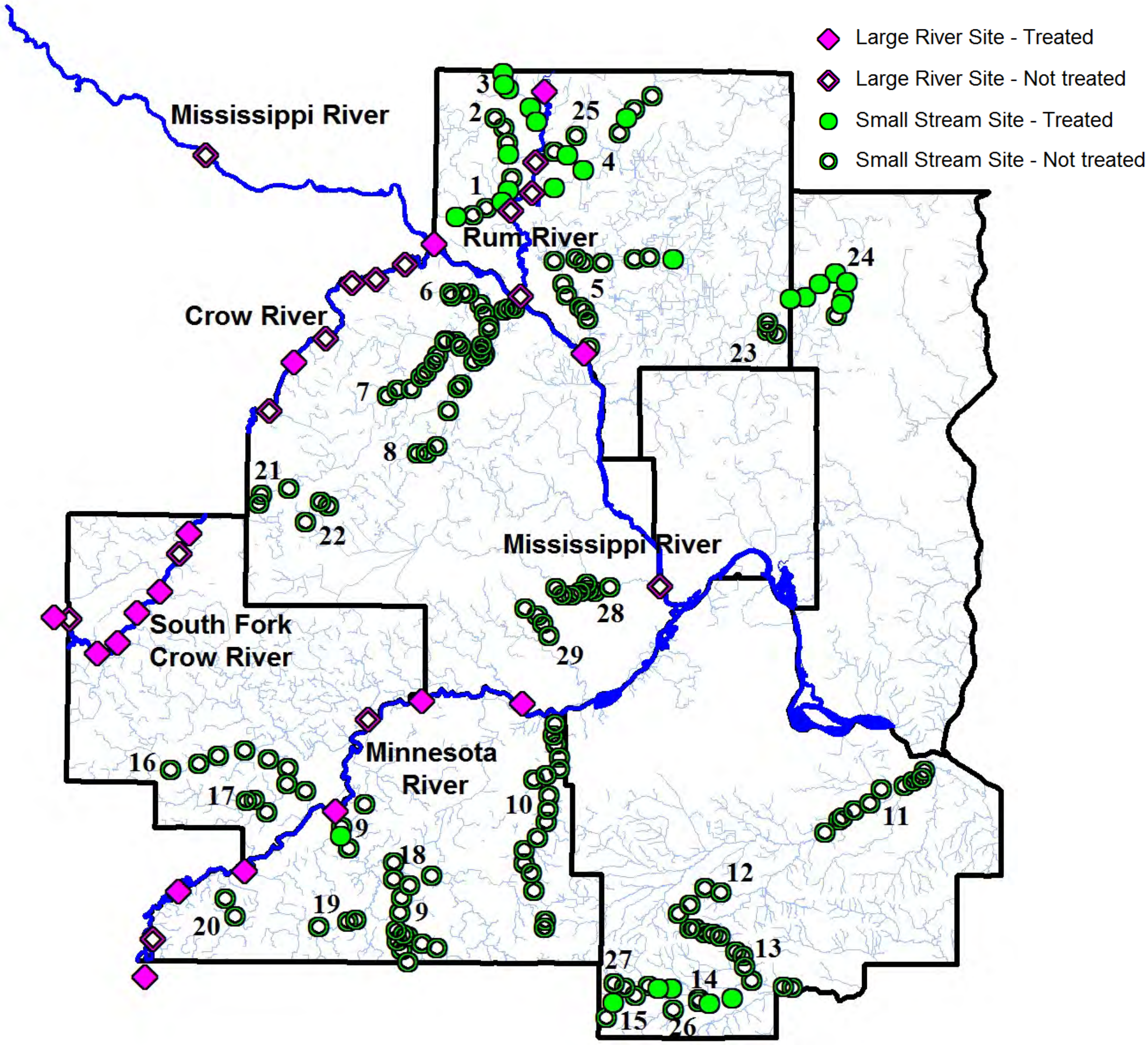


Figure 5.1 Large river and small stream black fly larval monitoring and treatment locations, 2019.

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	

Large River Program

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

The large river black fly larval populations were monitored weekly between 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.

Table 5.1 Summary of *Bti* treatments for black fly control by the MMCD, 2019 vs. long-term average

	2019			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	27	27	43.1	45.7	45.7	27.1
Large River						
Mississippi	2	9	1,520.0	2.1	10.9	1,172.7
Crow	1	2	107.5	2.2	5.3	96.8
South Fork Crow	6	12	185.0	5.4	12.0	103.8
Minnesota	6	10	2,396.6	6.0	16.3	1,678.2
Rum	1	8	153.0	3.5	19.9	143.1
Large River Totals	16	41	4,362.1	19.2	64.4	3,194.8

[1] The Mississippi, Crow, Minnesota, and Rum averages are from 1996 - 2018. The South Fork Crow average is from 2005-2018.

A total of 388 larval monitoring samples were collected from the large river sites in 2019. The treatment threshold was met in 41 samples from 16 of the permitted sites; the associated sites were treated with a total of 4,362.1 gallons of VectoBac 12AS *Bti* (Table 5.1). Due to flood-level flows that persisted throughout the spring, the first treatment on the Minnesota River was not done until June 12. The average amount of *Bti* used in the large river treatments annually between 1996 and 2018 was 3,194.8 gallons with an average of 64.4 treatments (Table 5.1).

The efficacy of the VectoBac 12AS treatments is measured by determining larval mortality 250 m downstream from the *Bti* application point after as many treatments as possible. In 2019, the average larval mortality of the treatments was 99.6% on the Minnesota River, 98% on the

Rum River, 88% on the Crow River, 92.1% on the South Fork Crow River, and 100% on the Mississippi River

Adult Population Sampling

Daytime Sweep Net Collections The adult black fly population was monitored at 53 standard stations (Figure 5.2) using the District's black fly over-head net sweep technique that was established in 1984. Samples were taken once weekly from early May to mid-September, generally between 8:00 AM and 10:00 AM. The average number of all species of adult black flies captured in 2019 was 1.80 ($\pm$ 7.80 SD). In comparison, the average of all species captured in net sweeps from 1996 (the start of operational *Bti* treatments) to 2018 was 1.27 ($\pm$ 0.81 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 ($\pm$ 3.04 SD).

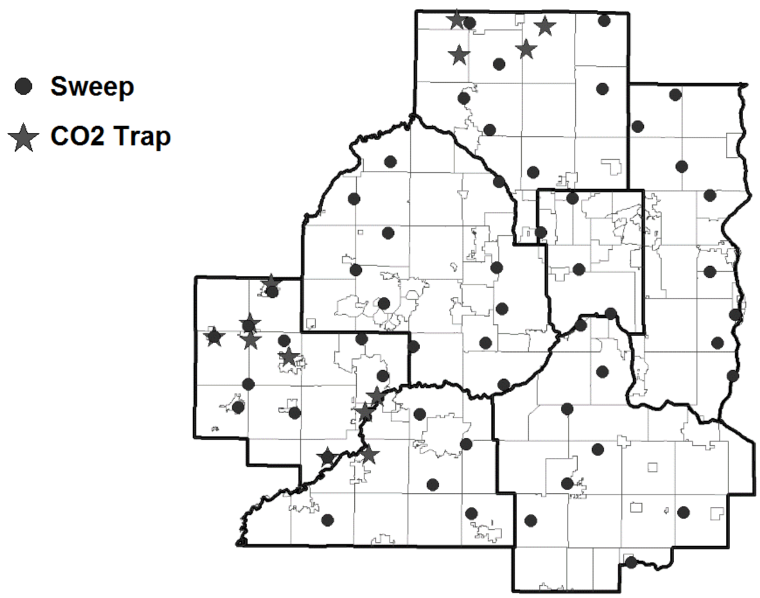


Figure 5.2 Adult black fly sweep and CO_2 trap sampling locations, 2019.

The most abundant black fly collected in the overhead net-sweep samples in 2019 was *S. meridionale*, comprising 77.8% of the total captured with an average of 1.40 ($\pm$ 7.50 SD) per sample. The second most abundant black fly species captured was *S. luggeri*, comprising 18.2% of the total captured with an average of 0.33 ($\pm$ 1.99 SD) per sample (Table 5.2).

The highest number of black flies captured in the net sweeps among the seven MMCD counties was recorded in Washington County with a mean of 2.76 ($\pm$ 8.32 SD) per sample. Scott County was second with a mean of 2.54 ($\pm$ 10.55 SD). Carver County was third in abundance with a mean of 2.39 ($\pm$ 12.48 SD) per net sweep. *Simulium meridionale* was the most abundant black fly captured in these three counties, with mean sweep counts of 2.68 ($\pm$ 8.24 SD), 2.42 ($\pm$ 10.56 SD), and 2.23 ($\pm$ 12.32 SD) in Washington, Scott, and Carver counties, respectively. The best *S. meridionale* larval habitat in the MMCD is located within reaches of the Minnesota River, particularly in the vicinity of net sweep sites in Carver and Scott counties.

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	1996-2018	1.27 + 0.81	0.99 + 0.78	0.01 + 0.01	0.16 + 0.12
	2019	1.80 + 7.80	0.33 + 1.99	0.001 + 0.03	1.40 + 7.50

[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 *S. luggeri*, *S. meridionale*, *S. johannseni*, and all other species collected.

Black Fly-Specific CO_2 Trap Collections Adult black fly populations were monitored from mid-May through June in 2019 with CO_2 traps at four stations each in Scott and Anoka counties, and five stations in Carver County (Figure 5.2). The adult black fly population at these stations has been monitored with CO_2 traps beginning in 2004. Black flies captured in these CO_2 traps are preserved in alcohol to facilitate species identification.

A total of 836,861 adult black flies were collected in the CO_2 traps in 2019 (Table 5.3). *Simulium meridionale* was most numerous, with a total of 835,194 captured that comprised 99.8% of the adult black flies captured in the CO_2 traps in 2019. 73.2% of the *S. meridionale* were captured in the Scott County traps, 26.57% in the Carver County traps, and 0.02% in the Anoka County traps. The mean number of *S. meridionale* captured per trap in Scott County was 11,347.24 (+ 20,317.80 SD), whereas the mean number per trap in Carver County was 3,318.10 (+ 10,572.80 SD), and 2.36 (+ 8.33 SD) in the Anoka County traps (Table 5.3). The large number of *S. meridionale* captured in Scott and Carver County was likely because no *Bti* treatments were done on the Minnesota River until June 12 because of high flows. In addition, *S. meridionale* populations in the Minnesota River were likely higher than normal coming into 2019 as a result of the ideal habitat conditions that lasted through much of the 2018 season; *Bti* treatments were also suspended on the Minnesota River in 2018 due to high flows.

Simulium venustum was the second most abundant species captured in the CO_2 traps in 2019; 774 specimens were collected that comprised 0.09% of the total number of black flies collected. The largest numbers were captured in Anoka and Scott counties with a mean of 6.89 (+ 17.56 SD) and 6.72 (+ 19.66 SD) per trap, respectively (= 0.05% and 0.04% of the total captured) (Table 5.3). *Simulium johannseni* and *S. luggeri* were the third most abundant species captured, both comprising 0.05% of the total captured. *Simulium johannseni* was most abundant in Carver

County comprising 0.03% of the total capture. *Simulium luggeri* was most abundant in Scott County, also comprising 0.03% of the total captured.

Table 5.3 Mean number of adult *Simulium venustum*, *S. johannseni*, and *S. meridionale* captured in CO_2 traps set twice weekly between May and mid-June in Anoka, Scott, and Carver counties, 2004-2019

	S. venustum			*S. johannseni*			*S. meridionale*		
Year	Anoka	Scott	Carver	Anoka	Scott	Carver	Anoka	Scott	Carver
2004	0.89	2.25	0.25	5.11	0.17	32.93	14.09	0.65	327.29
2005	2.31	3.40	0.84	0.03	3.50	99.04	1.23	23.25	188.02
2006	22.80	3.38	1.82	0.75	38.07	98.75	0.75	10.50	107.53
2007	37.62	35.59	75.67	0.20	32.50	112.77	0.51	172.48	388.64
2008	13.84	228.93	169.63	0.13	20.18	95.63	0.68	75.03	359.02
2009	18.32	238.16	425.00	0.34	22.80	35.92	0.70	98.77	820.25
2010	21.75	44.60	77.00	0.03	6.18	219.38	0.05	256.90	271.08
2011	8.90	60.64	48.30	2.61	280.64	*4,584.72	0.93	311.55	268.28
2012	2.89	5.45	0.40	0.95	81.73	154.13	0.41	242.55	100.53
2013	14.61	3.09	1.44	1.18	4.88	14.03	0.00	111.45	322.43
2014	13.64	16.82	8.68	3.36	12.36	702.82	1.32	12.64	193.57
2015	9.83	1.14	0.43	0.37	35.17	12.43	0.17	23.31	161.30
2016	1.70	0.72	0.02	1.50	2.89	35.41	0.86	64.33	501.85
2017	7.48	2.56	1.42	6.17	6.86	71.08	1.00	38.94	298.54
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
SD	+17.56	+19.66	+2.31	+1.86	+8.27	+12.40	+8.33	+20,317.80	+10,572.80
No. Traps	4	4	5	4	4	5	4	4	5

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

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 2019. Because these traps are operated for mosquito surveillance, samples are not placed in ethyl alcohol making black fly species-level identification difficult. Results are represented geographically in Figure 5.3. The areas in dark gray and black represent the highest numbers collected, ranging from 250 to more than 500 per trap. Very high number of black flies were observed in June in Carver, Scott, and Dakota counties with pockets of high numbers continuing into July (Figure 5.3). The peak average number of black flies occurred on June 4, greatly above the 12-year average (Figure 5.4). One collection on June 4 from Scott County contained an estimated 127,000 black flies! Above average populations continued through June 25 (Figure 5.4). These extreme numbers were the result of no treatments to the Minnesota River until mid-June due to flood conditions.

Media Attention The extremely high numbers of black flies experienced in 2019 resulted in increased media attention for the black fly program. While many local media outlets did stories, of note, was an article from the national publication, The Wall Street Journal titled 'Tiny Flies Are Coming for Your Blood – and Your Dignity" published June 16, 2019, which in part highlighted MMCD control efforts.

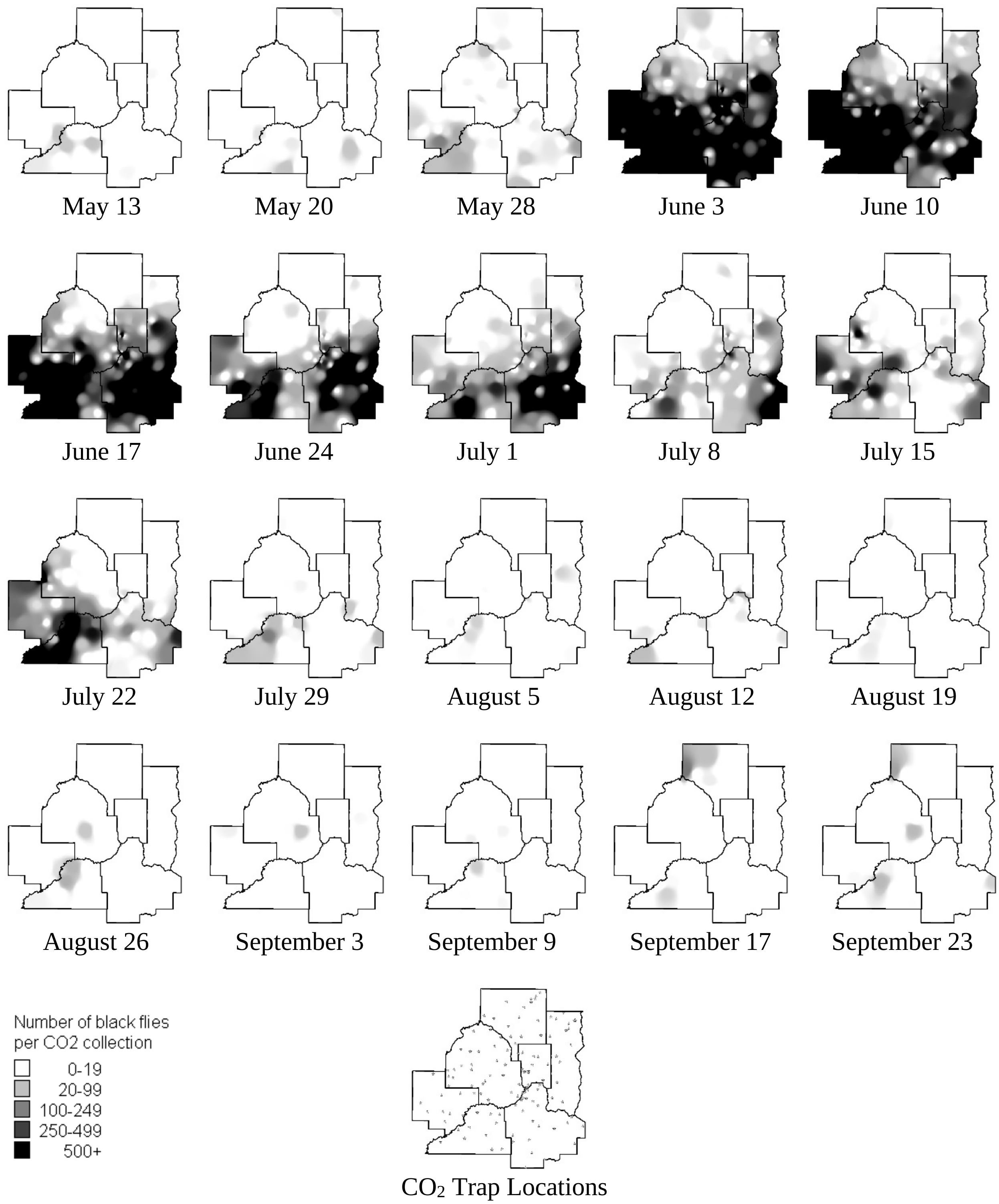


Figure 5.3 Number of black flies collected in mosquito surveillance District low (5 ft) and elevated (25 ft) CO_2 traps, 2019. The number of traps operated per night varied from 124-130. Inverse distance weighting was the algorithm used for shading of maps.

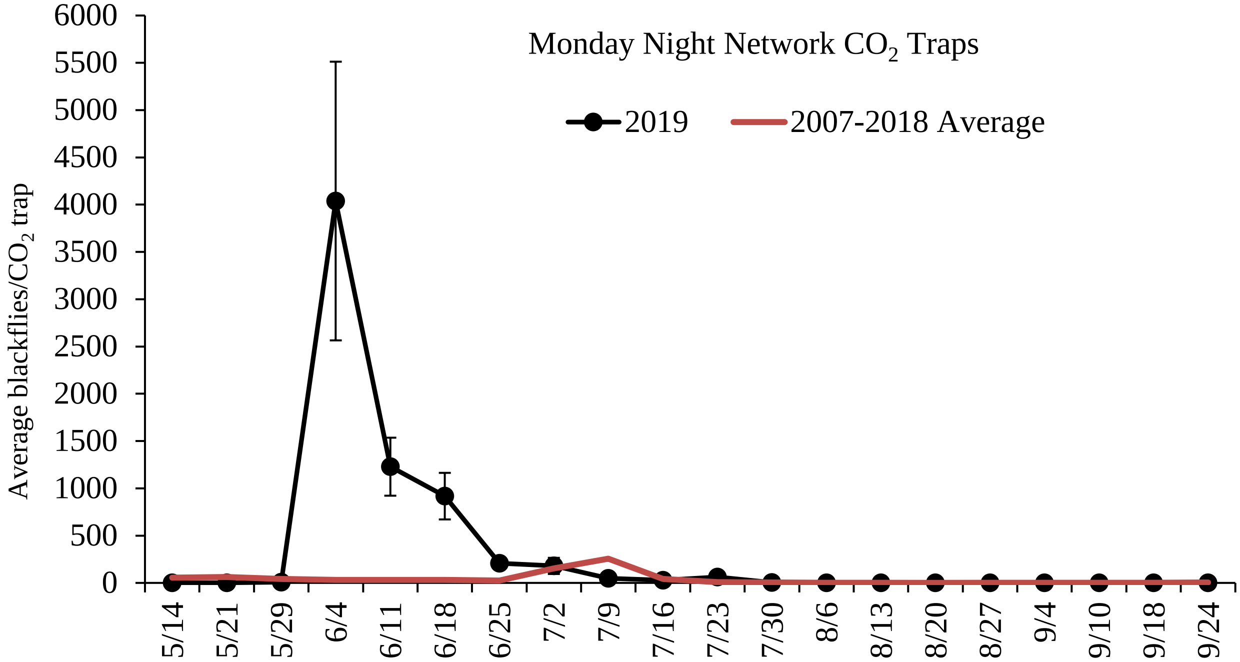


Figure 5.4 Average number of black flies per Monday Night Network CO_2 trap, 2019 vs. 12-year average (2007-2018). Error bars equal $\pm$ 1 standard error of the mean.

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 eleven 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 in 2019. These samples are being processed and a report is scheduled to be submitted to the MNDNR in 2021.

2020 Plans – Black Fly Program

2020 will be the 36th year of black fly control in the District. The primary goal in 2020 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. *Bti* will continue to be delivered from the manufacturer in bulk containers as part of the broader sustainability efforts of the District. The 2020 black fly control permit application will be submitted to the MNDNR in February. Processing of Hester-Dendy multiplate samples collected in 2019 for the non-target invertebrate monitoring program on the Mississippi River will continue. Program development will continue to emphasize improvement in effectiveness, surveillance, and efficiency. Larval and adult monitoring will continue on the Minnehaha Creek and nearby the neighborhoods in South Minneapolis where reports of large numbers of human-biting black flies have been reported in recent years. A study designed to compare non-target monitoring data collected on 14-plate Hester-Dendy multiplate samplers versus 7-plate Hester-Dendy samplers will be completed. The goal of this study is to determine if 7-plate samplers yield the same results as 14-plate samplers, which would allow for conducting the monitoring program in a more speedy, cost-effective manner.

Chapter 6 Product & Equipment Tests

2019 Highlights

- Both 8- and 5-lb/acre dosages of VectoBac® G *Bti* achieved good control of *Ae. vexans* in air sites
- Natular® G30 (5-lb/acre) effectively controlled *Ae. vexans* in air and ground sites
- Altosid® P35 (2.5-lb/acre) effectively controlled spring *Aedes* larvae
- Altosid® P35 (3-lb/acre) appeared to control *Cq. perturbans* in ground sites
- Altosid® P35, Altosid® pellets (both 3.5 g/cb) and VectoLex® FG (20 g/cb) effectively controlled mosquito larvae in catch basins

2020 Plans

- Test Altosid® P35 against summer *Aedes*
- Repeat emergence cages tests of Altosid® P35 to verify effective control of *Cq. perturbans*
- Explore 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.

2019 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 2019 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 granule (spinosad), 2019

		AI content		
Product evaluated	No. samples analyzed	Label claim	Analysis average	SE
Altosid XR-briquet	12	2.10%	2.18%	0.0040
Altosid pellets	12	4.25%	4.32%	0.0343
MetaLarv S-PT granules	12	4.25%	4.25%	0.0506
Natular G30 granules	12	2.50%	2.53%	0.0403

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 2019, 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 2019. Aerial *Bti* treatments began May 2 (eight days earlier than in 2018). We applied 8 lb/acre to control spring *Aedes* and switched to the 5 lb/acre rate beginning on May 25 to control *Ae. vexans*. We used the 5 lb/acre rate for the remainder of the season to conserve budgetary resources. In 2019, aerial *Bti* treatments averaged 85.9% control (Table 6.2), comparable to 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. Effectiveness of both rates was remarkably uniform throughout the 2019 season. Percent mortality was calculated by comparing pre- and post-treatment dip counts.

Table 6.2 Efficacy of aerial VectoBac G applications (8 lb and 5 lb/acre) during different time periods of the 2019 mosquito season (n = number of sites dipped)

Time period	Dosage rate	n	Mean mortality	±SE*
May 2 – May 20	8 lb/acre	123	88.9%	2.5%
May 25 – Sept 16	5 lb/acre	312	84.8%	1.8%
May 2 – Sept 16	All rates	435	85.9%	1.4%

*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 2019, we sampled Natular® G30-treated sites to compare with annual *Bti* efficacy evaluations. 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 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 2019 mosquito season (n = number of sites dipped)

Material	Dosage rate	n	% below threshold	% above threshold	Mean mortality	±SE*
Natular® G30	5 lb/acre	471	85.1%	14.9%	--**	--**
VectoBac® G	All rates	435	83.9%	16.1%	85.9%	1.4%

*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 2019 was designed to evaluate how different segments of mosquito control programs can be modified to deliver more mosquito control services to a greater part of the District area using existing resources. Much testing has focused upon controlling multiple mosquito species including potential vectors of WNV.

Larval Control

Altosid® P35 and *Coquillettidia perturban*s 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 6, 2019. On June 8, 2019, 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 11 through August 1, 2019.

Eighty-seven percent of adult *Cq. perturbans* (in terms of mean adult emergence per cage) from sites treated with Altosid® P35 emerged by June 17, that is during the first eleven days after treatment; thirteen percent emerged after June 17 (3.18 adults per cage by June 17 out of a total of 3.64 adults per cage by August 1) (Figure 6.1). Emergence in untreated sites was distributed more typically with a peak in late June (Figure 6.1). Ninety-eight percent of adult *Cq. perturbans* emerged from untreated sites after June 17 (0.04 adults per cage by June 17 out of a total of 2.16 adults per cage by August 1). Operational treatments with methoprene formulations typically are completed in late May (except for frozen sites treated in March), usually ten days earlier than when the sites in this test were treated with Altosid® P35. It appears that Altosid® P35 needed about ten days to control *Cq. perturbans* in these sites.

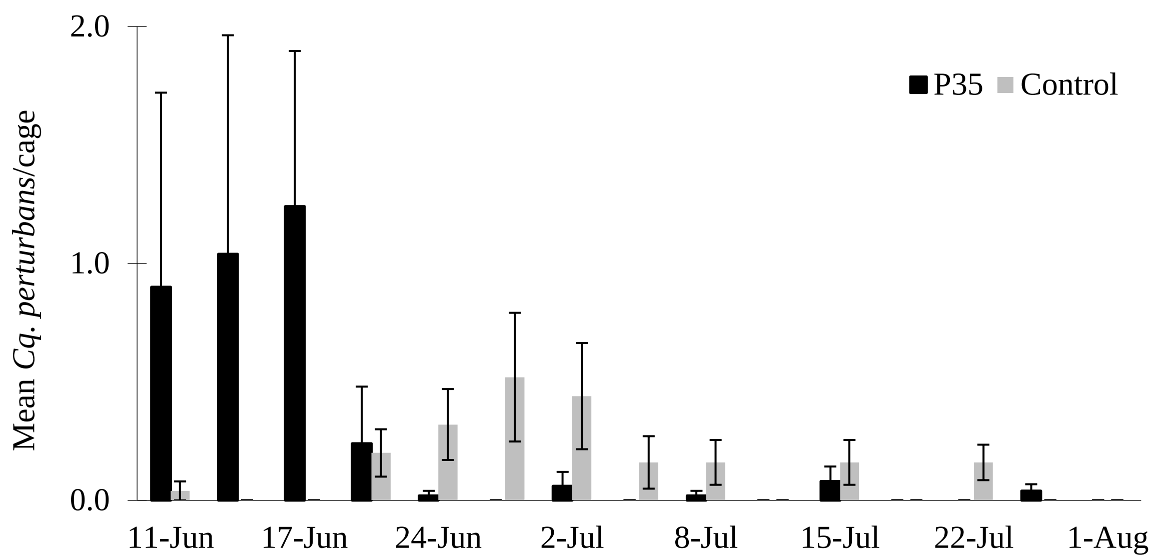


Figure 6.1 Mean emergence of *Cq. perturbans* per sample period in cages in rooted and floating sites treated with Altosid® P35 and untreated (control) sites. Emergence cages were placed on June 8 and sampling occurred from June 11-August 1, 2019. Treatments occurred on June 6 and June 7 (3 lb/acre). 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 and after the first eleven days of the sampling period (Table 6.4). These results also suggest that Altosid® P35 was successfully controlling *Cq. perturbans*. We need to repeat this test and treat sites with Altosid® P35 in late May, at least 11 days before emergence cages are placed, to better understand how well Altosid® P35 can control *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

Sample Period	Treatment	Total cages	Cages with emergence	Cages without emergence	% Cages with emergence	Fisher Exact P-value
8 June –	Untreated	25	17	8	68%	
1 Aug	Altosid® P35	50	15	35	30%	0.00156
17 June –	Untreated	25	17	8	68%	
1 Aug	Altosid® P35	50	6	44	12%	0.0000014

Altosid® P35 and Spring *Aedes* We treat some sites early in the season (mostly ground sites) with Altosid® pellets (2.5 lb/acre) to control spring *Aedes*. On April 26, 2019 we treated ten ground sites, and on May 9, 2019 we treated three ground sites with Altosid® P35 (2.5 lb/acre) to evaluate how well Altosid® P35 could control spring *Aedes*. Evaluating control is possible only if enough pupae can be collected from treated and untreated sites.

Pupal bioassays employ adult emergence inhibition (EI) that is calculated by dividing the number of pupae that did not successfully emerge (number of adults minus initial number of pupae) by the initial number of pupae. EI results for bioassays from Altosid® P35 treated sites are corrected for emergence in untreated sites (background mortality) using an Abbott's formula to correct bioassay data (Abbott 1987).

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

Thirteen bioassays were collected from sites treated with Altosid® P35. Altosid® P35 achieved excellent control of spring *Aedes* (Table 6.5). Mortality in all thirteen bioassays from treated sites was significantly greater than untreated control mortality (greater than the upper 95% confidence limit) (Figure 6.2).

Table 6.5 Bioassay results (pupal emergence inhibition=EI) of samples collected in Altosid® P35 treated (2.5 lb/acre) and untreated (control) sites

		EI (% mortality)				
	No. bioassays	Mean	SE*	Median	Min	Max
Altosid® P35	13	93.3%	3.15%	98.7%	62.3%	100.0%
Control	4	12.5%	5.2%	12.3%	0.0%	25.5%

*SE= standard error

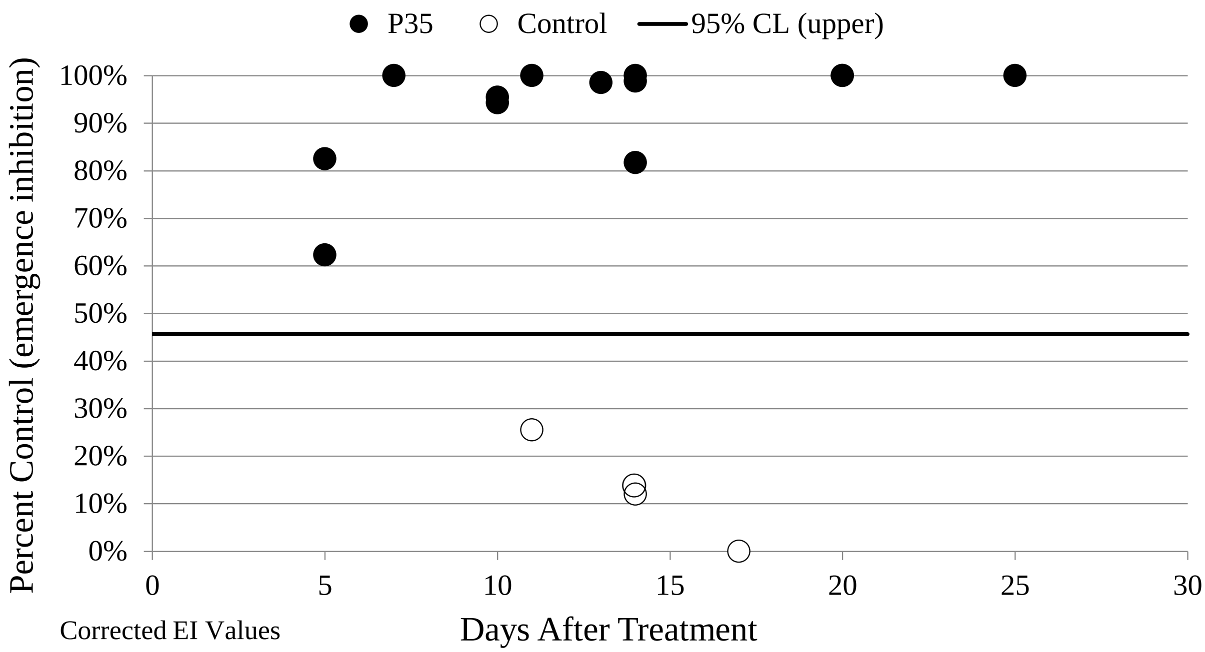


Figure 6.2 Bioassay results (emergence inhibition) of samples collected in untreated (control) and Altosid® P35-treated sites (2.5 lb/acre). Upper 95% confidence limits (CL) of untreated control pupal (background) mortality calculated using a t-distribution (df=3, t (0.05) = 3.18). "Days after Treatment" values for control bioassays was the number of days after April 26, 2019 that the control bioassay was collected.

Altosid® P35, Altosid® Pellet, and VectoLex® FG in Catch Basins Operationally, we treat catch basins three or four times each season with Altosid® pellets (3.5 g per catch basin) to control vector mosquitoes. 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.

Four groups of test catch basins were designated. All catch basins were in St. Paul. Ten catch basins were treated with Altosid® pellets (3.5 g per catch basin) on May 30, June 25, July 22, and August 22. Ten were treated with Altosid® P35 (3.5 g per catch basin) on May 31, July 5, August 9, and September 16. Ten were treated with VectoLex® FG (20 g per catch basin) on June 7, July 5, August 2, and September 6. Twelve 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 pupae for bioassays from untreated catch basins and catch basins treated with Altosid® pellets or Altosid® P35. We collected larvae from all catch basins. We also evaluated efficacy using the pass/fail strategy outlined by Harbison et al. (2019). Both Altosid® P35 and Altosid® pellets effectively controlled vectors based upon overall bioassay results (Table 6.6) (Figures 6.3 and 6.4).

Table 6.6 Bioassay results (pupal emergence inhibition=EI) of samples collected in untreated catch basins and catch basins treated with Altosid® P35 (3.5 g per catch basin) or Altosid® pellets (3.5 g per catch basin)

		EI (% mortality)				
Material	No. bioassays	Mean	SE*	Median	Min	Max
Altosid® P35	74	84.1%	3.2%	100.0%	0.0%	100.0%
Altosid® pellets	23	87.6%	4.7%	100.0%	46.8%	100.0%
Control	39	18.9%	4.4%	7.2%	0.0%	100.0%

*SE= standard error

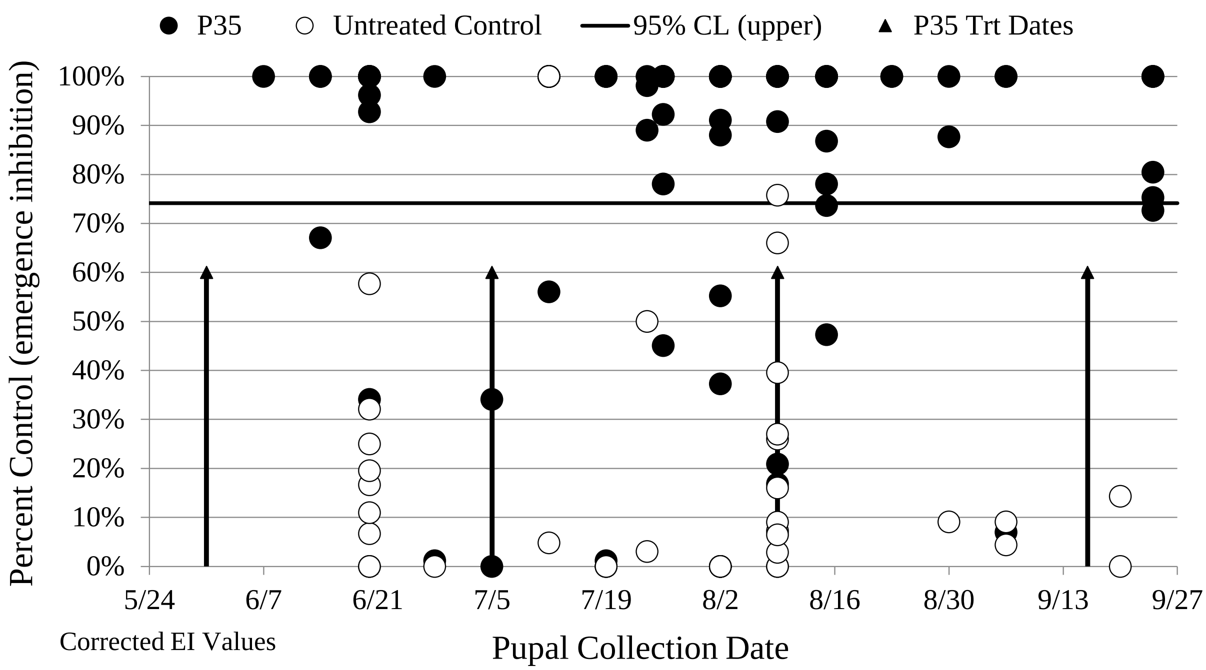


Figure 6.3 Bioassay results (emergence inhibition) from untreated (control) and Altosid® P35-treated catch basins (3.5 g per catch basin). Upper 95% confidence limits (CL) of untreated control pupal (background) mortality calculated using a t-distribution (df=38, t (0.05) = 2.02).

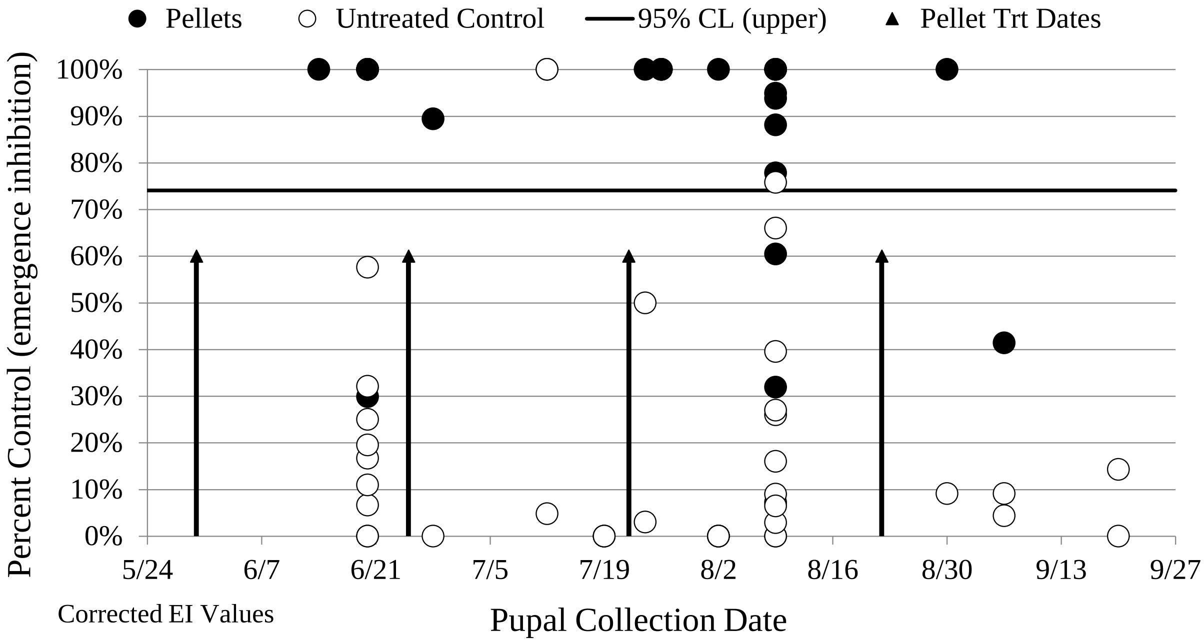


Figure 6.4 Bioassay results (emergence inhibition) from untreated (control) and Altosid® pellet-treated catch basins (3.5 g per catch basin). Upper 95% confidence limits (CL) of untreated control pupal (background) mortality calculated using a t-distribution (df=38, t (0.05) = 2.02).

Effectiveness of both Altosid® P35 and Altosid® pellets was high through 21 days after treatment. Effectiveness of Altosid® P35 began to wane more than four weeks after treatment (Tables 6.7 and 6.8). No bioassays were collected from catch basins treated with Altosid® pellets more than 21 days after treatment. Those catch basins were treated with Altosid® pellets every fourth week following the standard operational schedule.

Altosid® P35 and Altosid® pellets were less effective when evaluated using the pass/fail system for IGRs (fail = at least one adult emerges from pupal collection) (Harbison et al. 2019) (Tables 6.7 and 6.8). The failure rate for bioassays collected from catch basins 17-21 days after treatment with Altosid® P35 surpassed the retreatment threshold of 25% (Table 6.7). The failure rate for bioassays collected from catch basins treated with Altosid® pellets surpassed the retreatment threshold 11-15 days after treatment (Table 6.8).

Table 6.7 Bioassay results (pupal emergence inhibition=EI) of samples collected from catch basins treated with Altosid® P35 (3.5 g per catch basin) grouped by number of days post treatment. Results also evaluated by pass/fail (fail = at least 1 adult emerges from pupal collection)

	Days after treatment					
Altosid® P35	3-8	11-15	17-21	28	35	All bioassays
Mean EI	90.2%	85.7%	90.9%	75.9%	63.1%	84.1%
(n)	23	9	20	13	9	74
SE*	3.2%	10.9%	4.0%	10.1%	14.2%	3.2%
Min EI	48.5%	3.5%	37.5%	3.5%	0.0%	0.0%
Max EI	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Bioassays (n)**	20	7	18	9	5	59
>95% CL (%)	87.0%	77.8%	90.0%	69.2%	55.6%	79.7%
Fail	8	2	9	5	5	29
Pass	15	7	11	8	4	45
% Pass	65.2%	77.8%	55.0%	61.5%	44.4%	60.8%

*SE= standard error
** Number of bioassays with EI significantly greater than background mortality (EI > upper 95% CL for untreated control).

Table 6.8 Bioassay results (pupal emergence inhibition=EI) of samples collected from catch basins treated with Altosid® pellets (3.5 g per catch basin) grouped by number of days post treatment. Results also evaluated by pass/fail (fail = at least 1 adult emerges from pupal collection)

	Days after treatment					
Altosid® pellets	3-8	11-15	17-21	28	35	All bioassays
Mean EI	98.3%	80.9%	84.5%	--	--	87.6%
(n)	6	3	14	0	0	23
SE*	1.7%	19.1%	6.6%	--	--	4.7%
Min EI	89.7%	42.8%	31.6%	--	--	31.6%
Max EI	100.0%	100.0%	100.0%	--	--	100.0%
Bioassays (n)**	6	2	10	--	--	18
>95% CL (%)	100%	66.7%	71.4%	--	--	78.3%
Fail	1	1	7	--	--	9
Pass	5	2	7	--	--	14
% Pass	83.3%	66.7%	50.0%	--	--	60.9%

*SE= standard error
** Number of bioassays with EI significantly greater than background mortality (EI > upper 95% CL for untreated control).

The number of larvae collected from catch basins (untreated or treated with VectoLex® FG) varied during the sampling period (Figure 6.5). Catch basins treated with VectoLex® FG contained fewer larvae than untreated catch basins, although one might conclude that VectoLex® FG is not very effective because larvae still are present on many sampling dates (Figure 6.5). 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 one of seventeen weeks of sampling did VectoLex® FG-treated catch basins include over 25% scoring fail (Table 6.9, Figure 6.6). In contrast, over 25% of untreated catch basins scored fail during 14 of 17 weeks of sampling (Table 6.9, Figure 6.6).

The treatment dosage of VectoLex® FG was 20 g per catch basin which could be a bit cumbersome for operational use. In this test, four VectoLex® FG treatments were applied. The pass/fail retreatment recommendation would have indicated only one retreatment. We may consider testing different dosages to better determine the minimum dosage required to deliver the desired duration and degree of control.

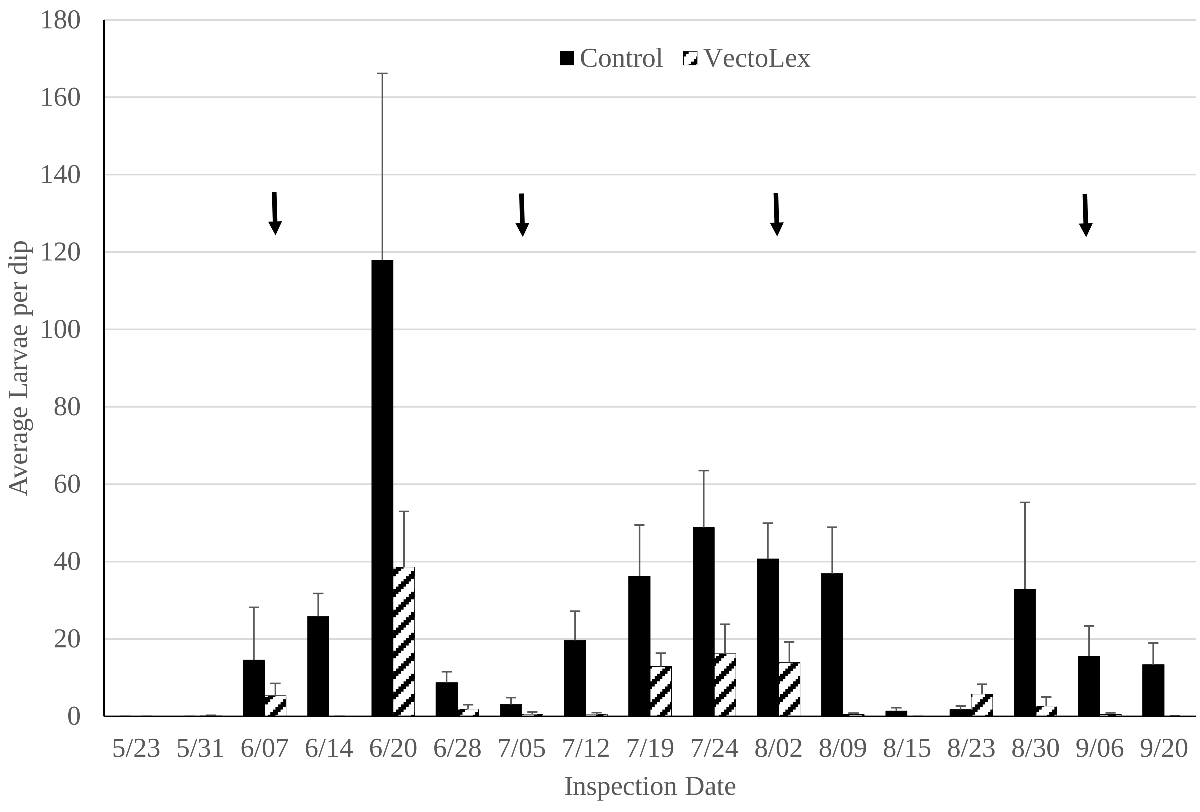


Figure 6.5 Mean number of larvae (all instars) from untreated (control) and VectoLex® FG-treated catch basins (20 g per catch basin) on each sample date. Error bars equal one Standard Error. Arrows indicate VectoLex® FG treatment dates.

Table 6.9 Percent of catch basins scored as fail from untreated (control) and VectoLex® FG-treated catch basins (20 g per catch basin) (Harbison et al. 2019). *SE= standard error

	% CBs fail/week		Number of weeks fail	
Material	Mean	(SE)	<25% CBs Fail	≥25% CBs Fail
Untreated Control	51.4%	(7.7%)	3	14
VectoLex® FG	6.9%	(3.3%)	16	1

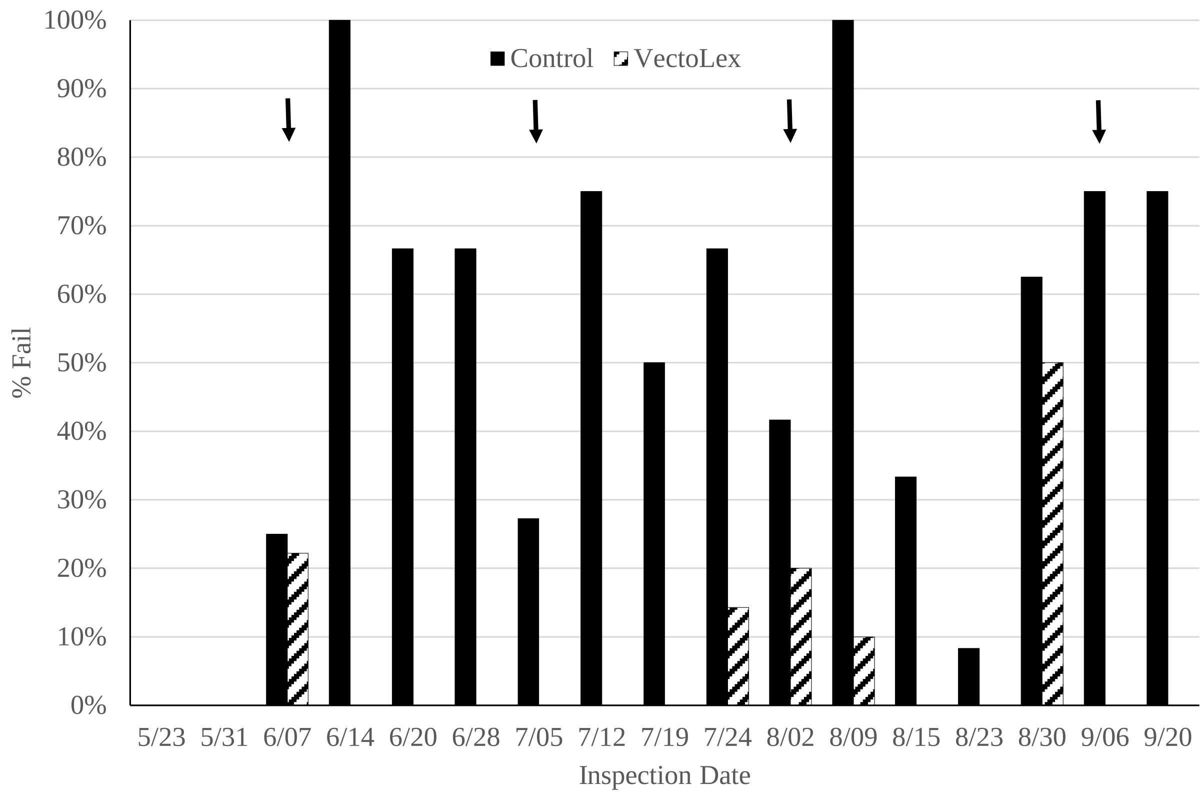


Figure 6.6 Percent of catch basins scored as fail (catch basins containing 3rd or 4th instar larvae or pupae) from untreated (control) and VectoLex® FG-treated catch basins (20 g per catch basin) each sample date (Harbison et al. 2019).

Adulticide Tests

We did not complete any tests of adulticides in 2019 because adult mosquito levels after mid-July (when service demands were low enough to free staff to conduct adulticide tests) were too variable to conduct high quality tests.

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 2019 season. These computerized calibrations directly calculate application rates and swath patterns for each pass so each helicopter's dispersal characteristics are optimized. Sessions were held at the municipal airport in Le Sueur, MN and Benson Airport in White Bear Lake, MN. Staff completed swath characterizations for seven different operational and experimental control materials. In total, seven Jet Ranger helicopters were calibrated, and each helicopter was configured to apply an average of four different control materials.

Drone Evaluations Technical Services aided in evaluating several control material application drones. In conjunction with vendors, MMCD conducted swath characterizations of two models of drones using our helicopter calibration system. The data collected assisted our drone team to evaluate and make decisions on which model would work best in field operations.

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

Optimizing Efficiencies and Waste Reduction

Recycling Insecticide Containers MMCD continued to use the Minnesota Department of Agriculture's (MDA) insecticide container recycling program. The Ag Container Recycling Council (ACRC) program focuses on properly disposing of agricultural insecticide waste containers, thereby protecting the environment from related insecticide contamination of ground and water.

Field offices collected their empty, triple-rinsed plastic containers at their facility and packaged them in large plastic bags for recycling. Each facility delivered their empty jugs to the Rosemount warehouse for pickup by the MDA contractor, Consolidated Container. MMCD arranged 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 1,089 jugs for this recycling program. The control materials that use plastic 2.5-gallon containers are Anvil 2-2 (37 jugs), Zenivex E4 RTU (74 jugs), *Bti* liquid (495 jugs), and Altosid pellets (483 jugs). A portion of the Altosid pellets and *Bti* liquid came in bulk totes, which significantly reduced the number of jugs generated in 2019.

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

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

Recycling Insecticide Pallets In 2019, MMCD produced over 573 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 2019, Clarke shipped all of our Natular G30 granules (100,800 lb) in 63 totes and reduced our packaging use by 2,520 bags. Central Life Sciences shipped a portion of Altosid pellets (22,000 lb) in 11 totes and reduced the packaging by 1,000 jugs. Valent also sent a portion of VectoBac 12-AS liquid (3,168 gallons) in bulk totes and reduced the packaging by 1,267 jugs. Staff was able to spend less time dealing with waste, and the District eliminated 4,787 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 2019, Valent BioSciences agreed to take back all of their products' waste packaging. Due to the quantity (880,677 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 11,008 lb was eliminated from the waste stream.

Hazardous Waste Collection In 2019, MMCD worked with the MDA to provide two regional sites for hazardous waste collection. The MDA provides a day each year that the public can properly dispose of any small quantity of hazardous waste free of charge. The District's Andover and Jordan facilities were used as collection points and MDA staff managed the safe handling of these materials. MMCD will continue to support this important public service to protect the environment.

Expired Product Disposal In 2019, 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. 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 reorganized the Oakdale Warehouse facility to increase efficiency and safe operations. The warehouse floor was resealed and made slip resistant. The berm in the mixing area was repaired and resealed. The mixing tank was thoroughly cleaned and remounted to reduce its size footprint. MMCD increased the amount of pallet racks to utilize more vertical space and remove obstacles. Pallet racks grates were mounted to increase the safety of loading materials. Overall, there were many additional revisions completed that will improve warehouse operations and support our safety culture.

References

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

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

2020 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.

In 2020, we will test Altosid® P35 against summer *Aedes*. We plan to repeat emergence cages tests of Altosid® P35 to verify effective control of cattail mosquitoes. Altosid® P35 is designed to be applied at lower dosages with current aerial application equipment which potentially could enable the District to support greater amounts of treatments with current budgetary resources.

We 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

2019 Highlights

- Utilized drones (UAS) for aerial photography and site scouting
- Began testing drones for granular treatment application, purchased one system
- Expanded use of catch basin editor to sync MMCD data with that available from cities
- Released report on MMCD/USFWS review of rusty patched bumble bee risks
- Launched new MMCD web site
- Sustainability – electricity use down 34% in the past six years overall

2020 Plans

- Continue testing drone-based granular treatments and how that process could fit into MMCD operations
- Improve tools for making drone-based aerial photography available for desktop and mobile maps
- Continue catch basin map improvements and test new ways to record treatments
- Start exploring electric vehicle options and infrastructure needs

2019 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. We have 13 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 2020 to become certified pilots.

Figure 7.1 DJI Mavic drone

In 2019, we purchased a third small quadcopter (another DJI Mavic 2 Zoom) and used that and our other two quadcopters (DJI Phantom 4 V2 and DJI Mavic 2 Zoom) 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 also flew drones to investigate rooftop habitats for mosquitoes where water was pooling on top of buildings in the state fairgrounds. 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 2019, we met with two companies (Leading Edge and Frontier Precision) with experience in applying control materials from UAS. Both companies visited the District and demonstrated their respective drones and applicators. We conducted calibration tests in the same manner we calibrate our helicopters (Fig. 7.2) and went to natural sites to simulate applications with blank materials. After testing the ability of the drones and each companies' software to successfully treat wetland habitat (including the ability for control materials to penetrate the tree canopy, Fig.7.3), the workgroup chose to proceed with the purchase of a PrecisionVision 22 UAS from Leading Edge with a 15-liter granular hopper.

In 2020, we plan to test the operation, ease-of-use, and effectiveness of granular applications 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 of 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.

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.

Figure 7.2 Calibrating PV-22 UAS + granular applicator.

Figure 7.3 Testing granule deposition under tree canopy.

Data Systems & Mapping

In 2019, we continued to improve our enterprise data and mapping system:

- New site mapping – mobile entry of inspection in a previously unmapped site now has a way to map location of new site within the inspection record
- Larval species ID entry moved from legacy system into web-based system, which completes our transition begun in 2013
- "Organic farm" added as a restricted access type, requires different restrictions
- Trails map layer added using data from a MetroGIS collaborative project
- Drone-collected photos – we are experimenting with processing options and developed a way to make these available in desktop GIS and in our mobile web app
- Catch basin map editing – the new web-based edit interface for mapping catch basins (WNV vector larval habitat, see Chapter 2) was put into use. We are in the process of collecting the most recent catch basin location data from cities and are using that to update our records (288,000 catch basins). The edit app allows view of both sets of data, and staff can field check and modify our records as needed (Fig. 7.4). City data unique identifiers are retained to make future data exchanges easier. We began testing tablets for data entry and possibly for entering treatment data as well.

Figure 7.4 MMCD (+,o) and City (x) catch basin map editor

Our 2020 projects include how to work with UAS mission planning and treatment recording software, continuing work with map editing, and moving to a larger cloud server.

MMCD's multiyear biological data sets are a valuable asset for research and analysis, both for basic questions and for ways we can more effectively and efficiently provide public service. We are making an effort to standardize and compile historical data to enable use by both MMCD and outside researchers.

Public Web Map MMCD's public access map on www.mmcd.org continues to let people see wetland inspection and treatment activity on our 81,639 sites in real time, and access history back to 2006. Activity data is updated automatically from our internal data system developed by Houston Engineering Inc. Now that the MMCD public web site has been updated (below), we are looking for additional ways to make useful data available to the public.

GIS Community MMCD staff participate in the MetroGIS collaborative, and we benefit from work by many other units of government. We use aerial photos collected by the Metropolitan Council and MnGeo, the state Geospatial Information Office, as well as those from metro-area counties as they become available. In 2020, we are supporting the Metropolitan Council's regional air photo acquisition in conjunction with the census. MMCD also uses basemap and geocoder services from the Metropolitan Council. We share our wetland data with others 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.

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

Figure 7.5 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 1993-2019. 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 2019, the DD_{40F} total went over 200 by the end of week 17 (April 27), comparable to the mid-range of dates in the last 20 years. Aerial treatments for spring *Aedes* (gray boxes) began near the end of the week following and were completed within two weeks (May 18).

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

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

Week #	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Last date in week (2019)
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	Mar 23
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	Mar 30
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	Apr 6
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	Apr 13
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	Apr 20
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	Apr 27
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	May 4
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	May 11
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	May 18
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	May 25
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	Jun 1
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	Jun 8
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	Jun 15

Figure 7.5 Cumulative Degree Days (base 40 °F, 4.4 °C) from January 1, MSP Airport.

Evaluating Nontarget Risks

Previous Nontarget Work At the direction of the TAB, MMCD has done studies over the years on possible nontarget effects of the control materials we use. Studies on Natular (spinosad) done in 2014-2015 have been discussed in previous Annual Reports. Earlier publications and reports on Wright County Long-term Study and other studies on *Bti* and methoprene done under the direction of the Scientific Peer Review Panel (SPRP) continue to be available on the MMCD web site, mostly as PDF files. The address is https://mmcd.org/non-target-impact-studies/.

Pollinators and Mosquito Control The status of pollinator populations (e.g. honeybees, native bees, butterflies, flies, etc.) continues to be a public concern, and MMCD has continued efforts to minimize negative effects on pollinators, including the rusty patched bumble bee (*Bombus affinis*) which was listed by the U.S. Fish and Wildlife Service as an endangered species under the Endangered Species Act effective March 21, 2017. Our biological control materials for mosquito larvae pose no risk to bees. For controlling adult mosquitoes, the pyrethroids we use as fog or barrier spray on vegetation, when used according to label, are relatively low risk for bees. The labels of all adult mosquito control products used by MMCD include specific restrictions designed to protect pollinators. Staff are trained to recognize pollinators and areas where pollinators may be active so they can adjust adult mosquito control operations to minimize exposure of pollinators.

In 2018, MMCD consulted with the U.S. Fish and Wildlife Service about the degree of risk of MMCD's mosquito control operations to the rusty patched bumble bee. We reviewed the annual biology of the rusty patched bumble bee with when and where mosquito control operations occur during the season and were able to conclude that the overall risk of MMCD's mosquito control operations to the rusty patched bumble bee is very low. The basis of this evaluation was a comparison of the biology of the rusty patched bumble bee and mosquito control operations, most notably adult mosquito control methods (see report on MMCD web site at https://www.mmcd.org/docs/publications/RustyPatchedBumblebeeReview.pdf.)

We continued to emphasize training staff about pollinator biology (including the rusty patched bumble bee) and how this biology relates to adult mosquito control. These training concepts apply to all non-target organisms, the monarch butterfly being a notable example (e.g., we train staff to identify and avoid milkweed, the foodplant of monarch butterfly larvae).

Since 2015, beekeepers who want to be eligible for compensation for losses due to pesticide exposure must register their hives through "BeeCheck", a FieldWatch system (https://www.mda.state.mn.us/plants-insects/bee-kills). The hive locations can be seen on DriftWatch (https://mn.driftwatch.org/map) or by logging in as a FieldWatch registered applicator. During our annual re-certification workshops for MMCD staff and for Minnesota Department of Agriculture licensed applicators, we provide information on BeeCheck and instructions on how to track hives using DriftWatch. MMCD staff also watch for hive locations when doing field work and modify adulticide treatments as needed.

Permits and Treatment Plans

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

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

In 2019, MMCD made no requests to conduct larval surveillance in wetlands within the MVNR due to Minnesota River flooding that made most areas of interest inaccessible for most of the season. Adult mosquito surveillance from CO_2-baited light traps near the Refuge (Fig. 7.6) indicated that *Ae. vexans* first appeared in most of the Minnesota River valley area traps on June 4. Collections of this species were highest from mid-June through late July. Traps DSR2, DSR7, and H291 were above threshold most of June and July, and FS1 was well above threshold for most of the year. Trap C015 was over threshold twice early in the year and then for three weeks in September. Traps S054, S015, and H127 (over two miles from Refuge) were not over threshold for this species more than once in 2019. Multiple flood events resulting in long-term inundation of the river valley likely reduced the productivity of sites within MVNWR for *Ae. vexans* in 2019.

Collections of *Cx. pipiens* and *Cx. restuans* were relatively low at locations near MVNWR in 2019, with only H291 showing over three nights above threshold. *Culex pipiens* and *Cx. restuans* serve as the enzootic or maintenance vectors of West Nile virus (WNV). Birds that move between the refuge and the surrounding area can be infected with WNV on or off the refuge then carry the virus to other areas and subsequently infect other mosquitoes on or near the refuge.

Culex tarsalis collections also remained low in traps near MVNWR for the entire 2019 season, with only H291 showing over three nights above threshold. The multiple flood events of 2019 resulted in near continuous flow of river water through the valley which may have reduced the likelihood of survival for *Cx. tarsalis* larvae that might have hatched in sites within MVNWR.

Mosquitoes collected from traps near MVNWR were tested for WNV from the middle of May through the end of September. There were no WNV positive samples from the area in 2019.

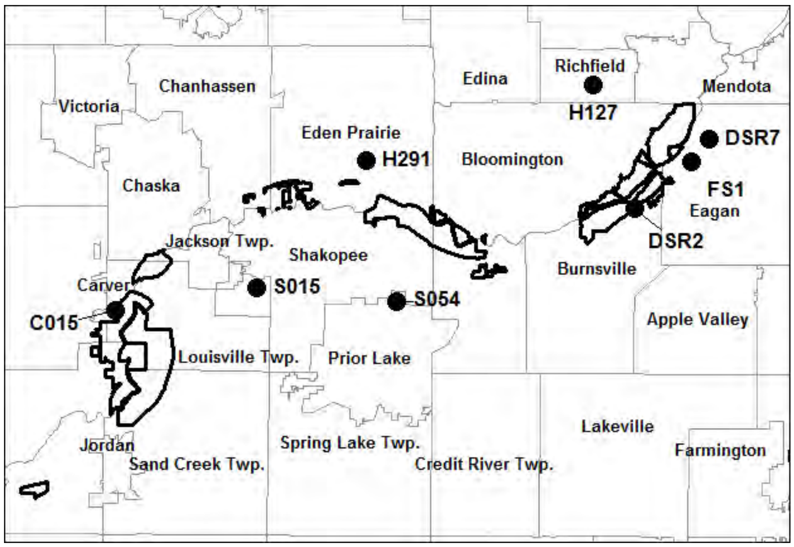


Figure 7.6 CO_2 trap locations (circles) near the MN Valley National Wildlife Refuge. Solid, dark lines delineate refuge boundaries.

Public Communication

Notification of Control The District continues to post daily adulticide information on its web site and on its “Bite Line” (651-643-8383), a pre-recorded telephone message interested citizens can call to hear the latest information on scheduled treatments. Aerial larvicide treatment schedules are also posted on the web site, Twitter, and on the “Bite Line” as they become available. Information on how to access daily treatment information is regularly posted on Facebook and Twitter. 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 2019, the number of these calls peaked the week of June 3, a few weeks before mosquito numbers were highest for the season in early July (Figure 7.7). Most of the calls in early June came from the northern part of the District, which coincides with the beginning of the emergence of mosquitoes in the corresponding parts of Anoka County (Figure 7.8).

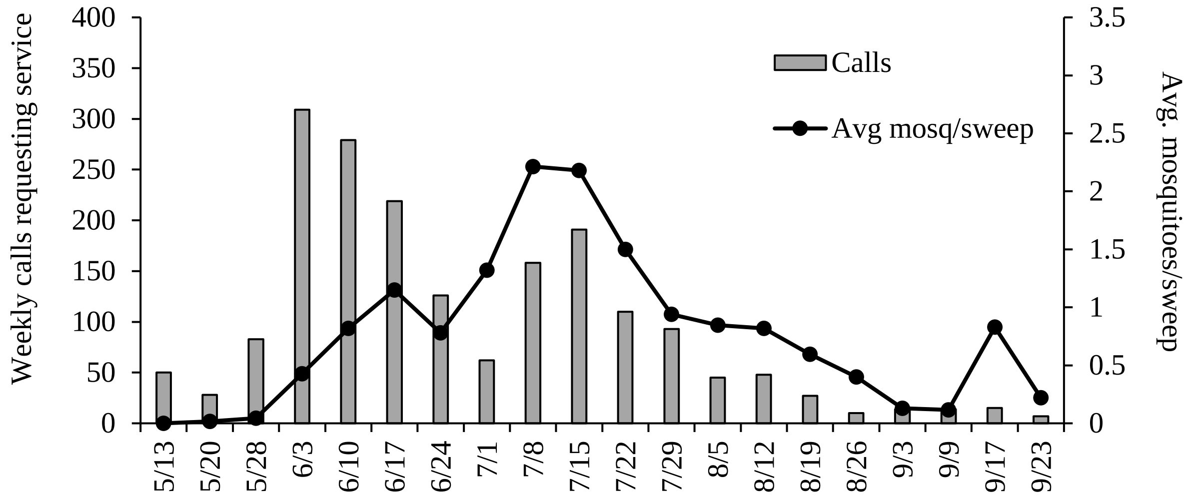


Figure 7.7 Calls requesting service, and sweep net counts, by week, 2019.

Figure 7.8 Call location maps for three weeks from June 3-24, 2019.

Requests specifically asking for adult mosquito treatment in 2019 were similar to previous years and calls requesting inspections of larval sites increased slightly over 2018, while still remaining below 2017 and 2016 (Table 7.1). Calls to request tire removal increased in 2019, which could be because we continued to promote this service even in winter months this year. Requests for treatment at public events and requests for “no treatment” remained steady in 2019.

Table 7.1 Yearly citizen call totals (including e-mails) by service request type, 2009-2019

	Number of calls by year										
Service request	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Check a larval site	197	164	626	539	609	1,068	447	886	1,151	601	802
Request adult treatment	594	1,384	1,291	1,413	1,825	2,454	1,633	2,499	1,157	1,212	1,144
Public event, request treatment	71	78	67	61	70	93	91	105	101	91	71
Request tire removal	305	332	315	417	351	429	366	377	363	325	411
Request or confirm limited or no treatment	58	53	56	54	[a]136	[b]146	139	158	126	75	69

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

Community and School Presentations Main Office and regional facility staff made presentations to 2,205 students in 23 schools during the 2019 calendar year. Nearly one quarter of students reached by MMCD's school presentations visited learning stations set up as part of multi-school field days where a variety of public agencies gave short, science-based presentations throughout the day. During 2019, staff also delivered at least 10 presentations to community groups including rotary clubs, environmental commissions, and community groups.

Public Events One of the most important ways that we educate the public is by interacting with people at community events. In 2019, MMCD staff worked 18 community events including county fairs, home and business expos, environmental events, and of course, the Minnesota State Fair. Between all these events we speak to thousands of District residents and educate on mosquito science, control, and school presentations and employment opportunities.

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 for the first time in 2019, Instagram. MMCD currently has 536 Twitter followers, up from 468 followers at the end of 2018, and 1,123 "Total Page Likes" on Facebook, up from 1,016 in 2018.

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. 2019 ended with 6,108 individual subscribers who opted in to receive some sort of communication from MMCD.

New Website In September of 2019, MMCD relaunched our website with a new design, new images, and a more organized format. The goal is to make the website an essential tool for District residents and employees.

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 focused on the following.

Reducing Energy Usage For electricity, we started in 2013 to reduce use through lighting and computer equipment upgrades, and in 2019 interior lights at the St. Paul office were replaced with LED lights. Electricity use in 2019 was 34% below the average baseline (2010-2014) suggesting that the retrofits have decreased usage District-wide. For transportation fuel, we have chosen more fuel-efficient vehicles, including smaller trucks and replacing vans with Prius models (three more in 2019). Staff have looked at work patterns, for example one office in 2019 reduced mileage by 1,500 miles by finding a local source of dry ice instead of driving to the St. Paul office. In 2020, we plan to explore electric vehicle options available on the MN State Contract and what infrastructure would be needed for their use.

Reducing Waste In 2019, we returned over 23,800 pesticide bags to the manufacturer, preventing 10,950 lb of waste, and returned 550 pallets for reuse. We have worked with manufacturers and expanded the use of reusable bulk totes to hold our materials. The District recycles all plastic control materials jugs through the national Ag Container Recycling Council (ACRC) program. The District also assists other agencies by being a collection point every other year for the ACRC program. Composting is widely used for items such as food scraps and paper towels. The St. Paul office has continued to promote compostable plates/cups/flatware for meetings and had 16.8 cubic yards of organics collected. Two regional offices repurposed tires into garden planters and produced fruits and vegetables on site.

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. Three of the solar gardens came on-line in 2019 (Oakdale, Maple Grove, and Plymouth). The other three are expected to go on-line 2020 when enough subscriptions are collected. By the end of 2019, 9.9% of the total power used in District operations was generated by solar energy, and we expect that to increase in 2020.

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. In 2019, we held our 6th annual shoe drive, donated 1,000 lb of food to our summer food shelf drive, continued prairie plantings, and started a pollinator friendly native garden. About 1,000 rodents collected for the Tick Distribution Study were donated to the Wildlife Science Center to help feed raptors in captivity.

Sustainability Culture The team is working to engrain sustainability into 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. This approach is similar to the safety culture we developed which significantly decreased employee injuries and vehicle incidents. In

August, we held our 2nd annual Sustainability Summit, involving 37 seasonal and full-time staff from throughout the organization. Each regional office presented successes and challenges, and the group worked on further ways to "reduce and reuse" throughout operations.

Professional Association Support

American Mosquito Control Association MMCD staff members continued to provide support for the national association: Diann Crane provides editorial assistance with the AMCA Annual Meeting Program and 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 northeast Washington County. The ultimate goals are to identify which species vector JCV to humans and whether or not the virus can be transmitted from adult mosquitoes to their progeny (transovarial transmission). Investigating potential insecticide resistance is also a goal for the MCE-VBD with colleagues across the region conducting bioassay tests for resistance. Also, conference calls with regional partners allow for the dissemination of trends in vector populations.

North American Black Fly Association John Walz served as President and Program Chair for this association again in 2019, and Carey LaMere maintains the association's website, http://www.nabfa-blackfly.org and produces the meeting program.

North Central Mosquito Control Association Mark Smith and Scott Larson served on the Board of Directors of this regional association focused on education, communication, and promoting interaction between various regional organizations and individuals in Minnesota, North Dakota, South Dakota, Wisconsin, Iowa, and the Central Provinces of Canada. MMCD hosted the 2019 meeting at Bunker Hills Regional Park, Andover, MN. The meeting qualified attendees for pesticide applicator re-certification for MN and ND. The 2020 meeting will be held in Fargo, 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 2019 and talks that are planned in 2020.

Publications

Fernandez, M.P., Bron, G.M., Kache, P.A., Larson, S.R., Maus, A., Gustafson, D. Jr, Tsao, J.I., Bartholomay, L.C., Paskewitz, S.M., Diuk-Wasser, M.A. 2019. Usability and feasibility of a smartphone app to assess human behavioral factors associated with tick exposure (The Tick App): quantitative and qualitative study. JMIR Mhealth Uhealth 2019; 7(10): e14769, DOI: 10.2196/14769.

2019 Presentations & Posters

Johnson, K. 2019. West Nile virus in 2018: *Culex* vectors of the North Central Region. Presentation: North Central Mosquito Control Association Annual Meeting in Andover, MN.

LaMere, C. 2019. MMCD Black Fly Control Program update. Presentation: North American Black Fly Association Annual Meeting in Twin Falls, ID.

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

Larson, S. 2019. “Taxonomy of Ticks and Laboratory Skills” and “Active Surveillance of Ticks Including Field Management Techniques.” Tick Integrated Pest Management (IPM) Academy, Madison, WI, November 6-7, 2019.

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

Manweiler, S. 2019. Mosquito control and the Endangered Species Act. Presentation: North Central Mosquito Control Association Annual Meeting in Andover, MN.

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

Read, N. 2019. Managing data on 288,000 storm drains with mobile mapping. Presentation: Minnesota GIS / LIS Conference, St. Cloud, MN.

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

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

Smith, M. 2019. Overview of the cattail mosquito program in Minnesota. Presentation: Ohio Mosquito and Vector Control Association in Perrysburg, OH.

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

2020 Presentations & Posters

Beadle, K. 2020. Controlling vectors using drone technology at the Minnesota state fairgrounds. American Mosquito Control Association Annual Meeting in Portland, OR. *Meeting cancelled*.

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.

Herrmann, C. 2020. Treating black flies on large rivers using a bulk treatment system to save staff resources and be more sustainable. American Mosquito Control Association Annual Meeting in Portland, OR. *Meeting cancelled*.

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

Manweiler, S. 2020. Controlling WNV vectors in Minnesota catch basins with Altosid® P35, Altosid® pellets, and VectoLex® FG. American Mosquito Control Association Annual Meeting in Portland, OR. *Meeting cancelled*.

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

Peterson, J. 2020. Utilizing drone technology to increase employee safety. American Mosquito Control Association Annual Meeting in Portland, OR. *Meeting cancelled*.

Smith, M. 2020. Employee morale – how mosquito program managers can support a quality work experience. American Mosquito Control Association Annual Meeting in Portland, OR. *Meeting cancelled*.

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

Appendices

Appendix A	Mosquito and Black Fly Biology and Species List
Appendix B	Average Number of Common Mosquito Species Collected per Night in Four New Jersey Light Traps 1965-2019
Appendix C	Description of Control Materials
Appendix D	2019 Control Materials: Percent Active Ingredient (AI), AI Identity, Per Acre Dosage, AI Applied Per Acre, and Field Life
Appendix E	Acres Treated with Control Materials Used by MMCD for Mosquito and Black Fly Control for 2011-2019
Appendix F	Graphs of Larvicide, Adulticide, and ULV Fog Treatment Acres, 1984-2019
Appendix G	Control Material Labels
Appendix H	Technical Advisory Board Meeting Notes

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.

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 Yearly Rainfall, 1965-2019. 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

*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 2019

The following is an explanation of the control materials currently used by MMCD. The specific names of products used in 2019 are given. The generic products will not change in 2020, 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 2019 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, 2011-2019.The actual geographic area treated is smaller because some sites are treated more than once**

Control Material	2011	2012	2013	2014	2015	2016	2017	2018	2019
Larvicides									
Altosid® XR Briquet 150-day	205	165	189	193	186	168	166	167	162
Altosid® XRG	13,336	23,436	6,948	52	0	0	0	0	0
Altosid® Pellets 30-day	30,749	13,172	15,813	26,179	31,494	19,173	17,939	10,202	12,020
Altosid® Pellets catch basins (count)	234,033	226,934	246,300	239,829	248,599	240,806	252,694	262,851	265,915
MetaLarv™ S-PT	0	2,750	14,063	18,073	21,126	33,409	23,740	23,574	23,003
Natular™ G30	0	9,524	15,000	14,950	8,840	13,023	12,271	15,662	17,277
Altosid® XR Briquet catch basins (count)	0	458	375	437	450	448	445	509	476
VectoLex® FG granules	0	0	2,330	3,064	3,777	6,076	4,773	4,660	5,036
VectoMax® CG granules	0	0	0	0	0	0	0	0	0
VectoBac® G *Bti* corn cob granules	201,957	207,827	150,280	255,916	258,148	234,120	136,173	134,926	156,089
VectoBac® 12 AS *Bti* liquid (gal used) Black fly control	3,817	3,097	3,878	4,349	4,351	3,112	3,621	3,234	4,362
Adulticides									
Permethrin 57% OS Permethrin	7,544	8,578	9,020	8,887	6,093	8,128	5,038	3,771	3,367
Scourge® 4+12 Resmethrin/PBO	24,605	8,078	37,204	44,890	19,767	23,072	2,090	0	0
Anvil® 2 + 2 Sumithrin/PBO	29,208	27,486	36,000	31,381	27,183	16,399	11,683	7,790	3,665
Pyrenone® Adulticide	0	0	0	0	0	0	0	0	0
Pyrocide® Adulticide	0	0	0	5,338	3,605	0	0	0	0
Zenivex® Etofenprox	0	0	0	0	10,380	34,984	23,097	26,918	15,289

APPENDIX F Graphs of Larvicide, Adulticide, and ULV Fog Treatment Acres, 1984-2019

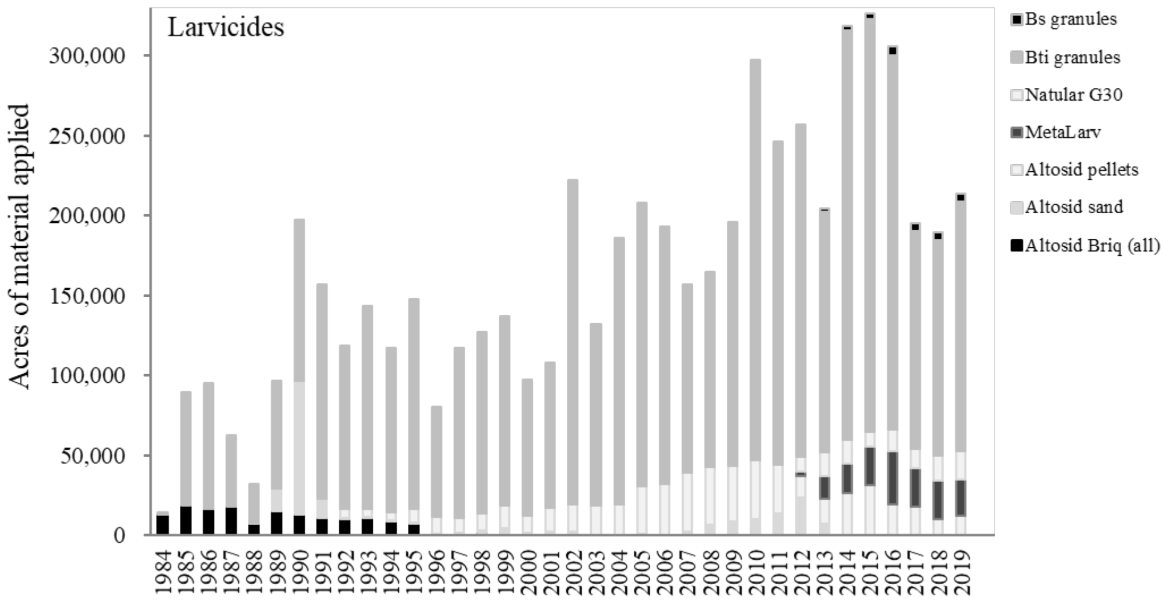


Figure F.1 Summary of total acres of larvicide treatments applied per year since 1984. For materials that are applied to the same site more than once per year, actual geographic acreage treated is less than that shown.

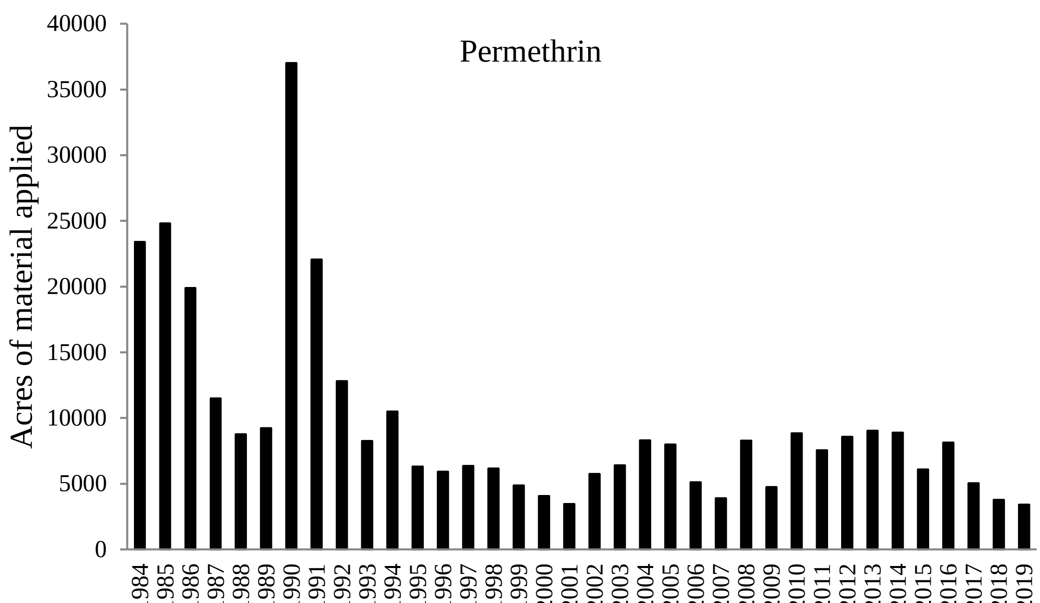


Figure F.2 Summary of total acres of permethrin treatments applied per year since 1984. This material may be applied to the same site more than once per year, so actual geographic acreage treated is less than that shown.

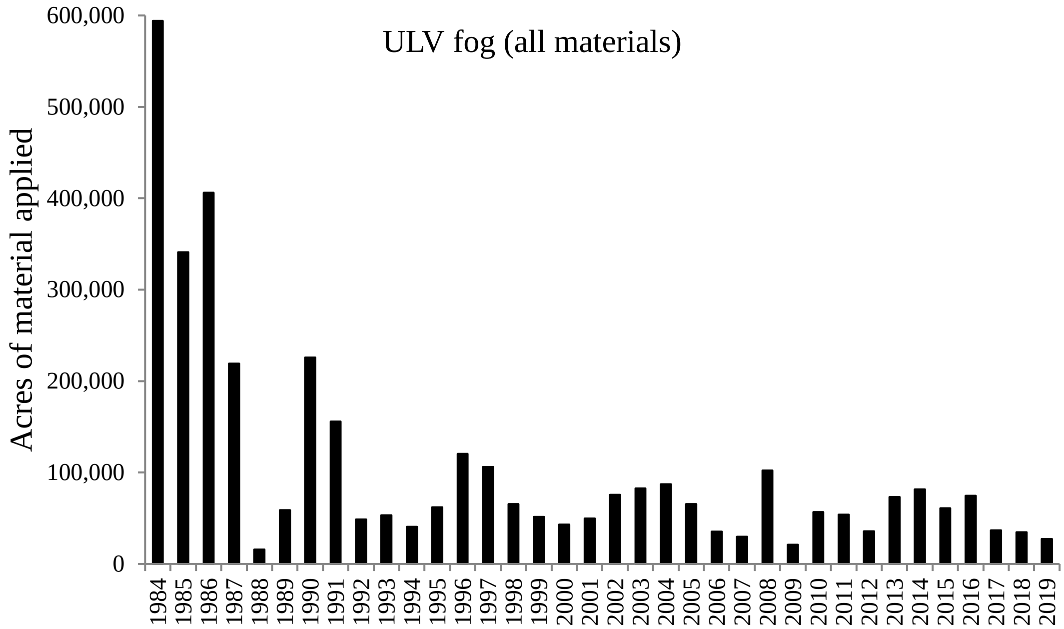


Figure F.3 Summary of total acres of ULV fog treatments applied per year since 1984. This material may be applied to the same site more than once per year, so actual geographic acreage treated is less than that shown.

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, 2020

TAB Members Present:

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

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: Elizabeth Schiffman (MDH), Molly Peterson (MDH), Jenna Bjork (MDH), Erin Kough (MDH)

(Initials in the notes below designate discussion participants.)

Welcome and Call to Order
Chair Gary Montz called the meeting to order at 12:30 p.m. and asked all present to introduce themselves. Gary then called on MMCD staff for their presentations.

Overview and Background
Stephen Manweiler presented background on budget, legislative issues, and employee changes. Service needs in 2014-16 resulted in MMCD using up budget reserves, resulting in reduced spending in 2017 and 2018, particularly in Priority Area 2 (P2). We have been able to shift some spending and with that, plus good conditions, we have been able to replenish reserves and will be starting to restore some spending. Legislative issues have been primarily related to pollinators and local pesticide control in some cities. As requested by TAB, we made our rusty patched bumble bee plan available for the public on our web site. Stephen introduced Alex Carlson, our new Public Affairs Coordinator, described the many other personnel changes in the past year, and our increased recruiting efforts.

SP – What amount is required for reserve? *SM* - $9 million. We use an algorithm to determine the amount.
SP – Which are cities of the 1st class? *SM* – Minneapolis, Saint Paul, Duluth, Rochester. *SK* – recent legislation versions regarding local pesticide regulations have included all cities.
SP – Regarding recruiting, many public health people I meet got their start as MMCD inspectors. Keep up the good work.

PM – Three neonicotinoids in the process of being listed as pesticides of concern, puts into motion some other best management practices, and may help regarding local pesticide issues. *SM* – Went to a stakeholders' meeting with Dept of Ag, and they recommended we educate the public about what we do, why and how we do it, and how we protect nontargets.

2019 Season Overview
Diann Crane described the categories of mosquitoes found in the District and their life histories and geographic occurrence. In 2019, temperatures were below normal for January – May, much more so in February, with heavy snowfall including an April blizzard, adding up to the wettest year on record. District-wide CO_2 trap counts were high, primarily in the outer areas that receive little treatment (P2). Rainfall was heaviest in the southwestern part of the District. Diann also showed shifts in the populations of *Anopheles quadrimaculatus* and *An. earlei* over the last 15 years.

SP – As *An. quadrimaculatus* range moves north, any evidence of malaria transmission moving north? *DN* – have not seen malaria further north. *Anopheles quadrimaculatus* are being found now as far north as Camp Ripley (near Little Falls, MN).
BS – Is there competition between some of these species? *DC* – not sure, *An. quadrimaculatus* can survive in a lot of different habitats and *An. earlei* is in forested areas.

Mosquito-borne Disease
Kirk Johnson presented an update on mosquito-borne disease in the District. It was a fairly quiet season overall. We continued LAC prevention efforts, no cases of LAC in MN, have had none in the District since 2016. WNV still active in U.S. with 46 fatalities elsewhere, but only three cases in MN, two of which were in the District, and only five mosquito pools were positive for WNV. Virus activity appeared much later in the season than in 2018. We also found few *Cx. pipiens*, one of the main vectors, and *Cx. tarsalis* abundance was also low. However, it was a higher than normal year for EEE in other parts of the US, with a high mortality rate. Some horse and grouse EEE positives were found in MN. There were low vector numbers in the District, and no EEE was found. JCV was found in four metro area residents, apparently exposed outside MMCD. We did find JCV in some MMCD samples of spring *Aedes* mosquitoes.

SP – With *Cx. pipiens* and *Cx. restuans*, are larvae easier to determine to species than adults are? *KJ* – yes in all but the first instars.
GM – Any idea why there was a reduction in WNV this year? *KJ* – It's a complex cycle so any one of a lot of factors could cause it. For instance, a cool spring which makes for a late start to WNV transmission or low numbers of vectors that year. WNV seems to occur more strongly in a cycle; there will be 3-4 years of high transmission then a few years of lower WNV circulation. This multi-year cycling could perhaps be due to variance in bird infection levels.
JM – How tightly correlated are Jamestown Canyon outbreaks and the deer population? *KJ* – We can't discount that that is a factor.

Spring *Aedes*
Nancy Read described more about MMCD's "spring *Aedes*" group including the seasonality of larval abundance for various species, and the contribution of spring *Aedes* to human annoyance and disease risk based on Priority Area 1 (P1) sweep samples. In 2017, as part of our cost-cutting measures, we eliminated spring *Aedes* treatments in the outer, less populated area of the District

(P2). At a previous meeting, TAB members raised concerns about Jamestown Canyon virus and the possible role of spring *Aedes* as vectors. In 2018, we pushed larval surveillance and treatments into parts of P2 where there were significant human populations and where we could find some history of larval production, but, in 2019, increased larval production in P1 used most of the available resources. In the past, we have used a lower larval count threshold for treatment for spring *Aedes* because the larvae are difficult to catch, and the adults have a longer lifespan than regular summer species such as *Ae. vexans*. We raised the spring *Aedes* P1 threshold to 1 per dip (up from the previous 0.5 per dip) in 2018-2019 because of low numbers of adults in P1. We have been considering ways to enable more work in P2 where spring *Aedes* populations are higher and JCV has been found, possibly including raising the P1 spring threshold, but are concerned about maintaining protection for high human population areas.

SK - Is that area with high spring *Aedes* levels close to Carlos Avery State Wildlife Management area? *NR* – Yes.
DN – I would encourage you to do some control in areas known to have JCV in mosquito populations. It's poorly understood how JCV is distributed across the landscape, although I suspect it's more localized. With both two-year persistence of the virus and two virus-infected vector species, the Scandia area strikes me as a focus of JCV virus that is likely well-established. This is a good opportunity to gather more data on virus persistence, the size of the focus, and the potential vector species involved. In addition, there are decent numbers of folks in that area who might benefit from additional spring *Aedes* larval control.
BS – MMCD has a lot of data generated over the years. It's hard to collate it all in our minds. Consider the methods of Hans Rosling on how to display timeseries data using animations. It would be worth doing on at least some data sets.

Tick Surveillance

Janet Jarnefeld presented data on tick populations. The number of sites positive in MMCD has increased over time, although 2019 numbers have declined slightly from the previous year. Janet also presented information on ticks introduced or expanding into Minnesota, including *Amblyomma americanum*, the lone star tick, and *Haemaphysalis longicornus*, the Asian longhorned tick. MMCD is part of an active, inter-agency group working on Asian longhorned tick surveillance. Janet also reported that MDH staff had reported the first known localized introduction of *Amblyomma maculatum*, the Gulf Coast tick, in Minnesota. MMCD staff will continue to provide tick surveillance, keep watching for introductions of non-native ticks, and engage the public in education and assistance with detecting any non-native ticks.

SP – Did the Gulf Coast tick come from someone with a travel history? *JJ* – No travel history.
DN – No travel history, tick may have come in on a bird, more of that may be occurring.

Break

Black Fly

Carey LaMere reported on the black fly situation in 2019. Very high water in the Minnesota River prevented treatment early in the season leading to unusually high black fly numbers early in the year in the southwest portion of the District, which again garnered media attention. For non-target monitoring we are continuing testing smaller multiplate samplers to see if that would provide similar results for less effort. River flood projection for 2020 is >50% chance of flooding. Carey described some options for addressing flooding in the future.

JM – Regarding the video, it talks about fewer gnats historically – graph showed more gnats 30 years ago? *CL* – Yes, we have to go back longer to get to a time when affected by water quality. *BS* – I've read that early surveyors in MN had to work in groups of three: one for the rod, one for transit, one to keep the mosquitoes and black flies off the one trying to read the transit.

Control Materials – Efficacy Tests

Stephen Manweiler described some of the efficacy testing done in 2019. Altosid P35 is a new methoprene formulation that has a more uniform size that can allow us to use less material to achieve a similar level of control. Tests on cattail mosquitoes showed good results after the first 10 days; we plan to repeat this test in 2020 and apply the treatment earlier to make sure the material has time to work. Bioassay results for control of spring *Aedes* showed significant control. We also evaluated treatment of catch basins with P35 using both bioassay data and a "pass/fail" system developed by Harbison and Nasci. Another material, VectoLex FG, was also tested for potential use in catch basins and showed it reduced larval mosquito populations.

SK – How do you dose the catch basins? Is P35 better? *SM* – We use a scoop to measure the correct amount (3.5 grams). That was a challenge to find. It will be easier with new formulations.

Drone Update

Scott Larson described drone usage for mosquito control in general and MMCD's plans. Districts in several other parts of the country are starting to use drones for treatment. We have used drones to acquire new photos for mapping, for looking for standing water on rooftops, and for investigating some treacherous or large sites. In 2019, we tested two kinds of drones for granular larval treatments and purchased one that we will be testing in 2020. We also received a COA (certificate of authorization) from the FAA for drone use. We have 15 staff members licensed as part 107 drone pilots.

BS – As you pilot the drone, do you have camera view as you fly? *SL* – yes for camera drone, it looks down. The treatment drone only has forward facing camera; the hopper sits where a camera that looks down would be placed. To fly it, the pilot always needs to have the drone in his/her line of sight, but you can also see the drone's location on a map on the controller.
SK – Is anyone in mosquito control looking at multispectral or hyperspectral imagery? *SL* – We have tried some thermal and multispectral, hoping to find open water pockets in cattail sites. *SK* – Talk to Ian McRae about what he's doing looking for spotting disease and insect damage in crops. It would be great if you could identify signatures for mosquito habitats.
SK – Are there fill caps on the hoppers? *JM* – If it tipped over what would happen? *SL* – We can get some caps.
CW – Do you have an incident response plan? *SM* – we have one for helicopters, and we can put together a similar one for drones. *NR* – COA application (submitted to FAA) addressed some things, but it doesn't specifically address treatments.
SL asked the group if their agency was using drones, and if so, for what?
VS – Our law enforcement was using drones, Fed has shut down drone use for the moment, we have a policy in place.

JM – Talk to Three Rivers about what we can work out for treatments.
CW – Dept of Ag has used drone for photos of spill sites and irregular damage.
GM – DNR has a fair amount of interest and have a workgroup exploring drone use. DNR workgroup staff may want to follow up with MMCD staff to see how you have addressed various regulatory issues relating to drone use.
CS – MNDOT has a shared drone service within the agency that works with individual departments on their projects. He suggested that the MNDNR contact them to get advice on setting up drone use.
NR – The City of St. Paul suggested setting up Part 107 training between agencies.

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

Discussion and Resolutions

Chair Gary Montz noted that he was pleased MMCD had handled the TAB's prior year concerns regarding the rusty patched bumble bee and *Culex pipiens* as well, and opened the floor for discussion and possible resolutions they would like to put forward to communicate with the MMCD Commissioners.

Discussion: TAB members are interested in further uses and treatments with drones and would like to be kept informed as tests are done. *CW* reconfirmed that the MN Dept. of Ag's Category B (Aerial Applicator) licensing, plus using a material registered for aerial application, and an FAA/MnDOT licensed drone is sufficient for treatment at the moment.
DN is satisfied with the direction MMCD is headed in the area of vector-borne disease.
BS noted that MMCD has been very good about finding, researching, and addressing new technologies and taking care of problems as they arise. He commends MMCD on its alertness and awareness of methods and technologies to address problems MMCD is facing.

The following were drafted by TAB members, discussed, and voted on.

Resolution: The TAB supports the program presented in the 2019 Operational Review and 2020 Plan and acknowledges the efforts of the MMCD staff on its presentation.
Motion to approve made by *JM*, Second *RS*
Motion passed without dissent.

Resolution: The TAB commends MMCD on your ability to manage budgets and keep focused on the tasks needed, including being prepared for emergencies and emerging issues.
Motion made by *PM*, Second *JM*
Motion passed without dissent.

There being no further discussion, the TAB adjourned at 3:30 p.m.

Our Vision

To be the leading mosquito abatement district in the world

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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