METROPOLITAN MOSQUITO CONTROL DISTRICT
2023 OPERATIONAL REVIEW & PLANS FOR 2024

Annual Report to the Technical Advisory Board

From left to right clockwise: Technicians dragging for ticks, sampling woodlot for Aedes triseriatus, sampling the river for larval black flies.

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 2024

Julie Jeppson	Anoka County
Mandy Meisner	Anoka County
Jeff Reinert	Anoka County
Gayle Degler	Carver County
Tom Workman	Carver County
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Rena Moran	Ramsey County
Mai Chong Xiong	Ramsey County
Dave Beer	Scott County
Tom Wolf	Scott County
Gary Kriesel	Washington Co.
Fran Miron	Washington Co.

Technical Advisory Board

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

Technical Advisory Board Members 2023-2024

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Jacob Bova	US EPA
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Arleen Schacht	Business Administrator
Diann Crane	Entomologist
Janet Jarnefeld	Technical Services/Tick
Kirk Johnson	Vector Ecologist
Carey LaMere	Technical Services/Black Fly
Scott Larson	Assistant Entomologist
Alex Carlson	Public Affairs Manager
Nancy Read	Data Systems Coordinator
Mark Smith	Technical Services Manager
John Walz	Technical Services/Black Fly
Jon Peterson	District Operations Manager

DEPARTMENT OF HEALTH

Protecting, Maintaining and Improving the Health of All Minnesotans

April 6, 2023

Commissioner Fran Miron
Chair
Metropolitan Mosquito Control Commission
2099 University Ave West
St. Paul, MN 55104

Dear Commissioner Miron,

The Technical Advisory Board (TAB) met on February 7, 2023, to review and discuss MMCD operations in 2022 and plans for 2023. Since the Board's formation in 1981, the member representatives have met at least once per year to provide an independent review of field control programs and to enhance inter-agency cooperation.

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

Resolution #1 – The TAB supports the program presented in the 2022 Review and 2023 Plan and acknowledges and appreciates the efforts of the MMCD staff in its presentation.

Resolution #2 – The TAB encourages the MMCD Commissioners to keep a requirement that the Director has an entomological or biological background, so science continues to drive MMCD decisions.

Resolution #3 – The TAB thanks the MMCD for developing a strong Integrated Vector and Pest Management program based on prevention and reducing the need for reactive techniques for pest management such as adulticides. The TAB urges the Commission to continue this emphasis, including ensuring that the budget must be based on preventative measures.

Resolution #4 - The TAB supports the District's intent to explore collection of updated public input to inform its practices.

Sincerely,

Elizabeth Schiffman, MPH, MA
Chair, Technical Advisory Board

Minnesota Depart of Health
Infectious Disease Epidemiology, Prevention, and Control Division
St. Paul, MN 55164
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Executive Summary

For over 65 years the Metropolitan Mosquito Control District (MMCD) has sought to provide cost effective service and accomplish our stated 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. This report presents MMCD efforts to accomplish this mission in 2023 through surveillance, disease monitoring, control measures, new product testing, data management, public communication, and other projects. It also presents plans for 2024 as we continue to provide an integrated mosquito management program for the benefit of District residents.

Mosquito Surveillance

After a winter with significant precipitation and wet conditions in early spring, the District faced drought conditions during the summer for the third year in a row. The snowfall total from the winter of 2022-23 was 90 inches, which was 39.1 inches above normal. Beginning in mid-May precipitation remained below average through early September and most of the seven-county metro was categorized as having moderate to extreme drought.

Adult spring *Aedes* emerged May 16 and peaked May 31. Spring *Aedes* mosquitoes were more abundant in 2023 than any year in MMCD history at levels approximately five times greater than average. However, summer *Aedes,* which are the primary pest mosquitoes in most years, had their main emergence on May 31 and they peaked on June 6, although their abundance was less than half that of an average year. Populations of the cattail mosquito, *Coquillettidia perturbans*, which depend on adequate water levels in their marsh larval habitat from the previous fall through adult emergence in early July, were well below normal, but about what was expected based on previous history. The extremely low water levels in fall of 2023 reduced larval habitat for this species, and we expect adult populations to remain low in 2024.

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.

The Minnesota Department of Health reported 43 WNV cases in 2023 with 19 occurring in District residents. The hot, dry conditions favor development of the vectors of WNV, unlike many other mosquito species which are more productive in wetter years, which partially explains why MMCD documented a new record WNV infection rate in mosquitoes tested in 2023. There were two cases of JCV in Minnesota in 2023, which were reported in residents of Ramsey and Anoka counties. There was one case of LAC reported in the District in a resident of Scott County.

The District continued monitoring the distribution of ticks in the metro area. In 2023, the District again collected *I. scapularis* from at least one site in all seven counties. As has been the case in

our counties north of the Mississippi River for many years, there are now many areas south of the river where residents might encounter *I. scapularis*. In addition to the regular tick collecting by small mammal trapping, MMCD also surveyed 25 natural areas across the metro with a method known as dragging. The ticks collected from these samples were sent to either the CDC or MDH for pathogen testing.

No tick-borne disease case data is yet available for 2022-2023. There were 1,033 confirmed Lyme disease cases and 603 confirmed and probable human anaplasmosis cases in Minnesota in 2021.

Mosquito and Black Fly Control

MMCD's program focuses on control of mosquitoes while they are in the larval stage and uses the insect growth regulator methoprene, the bacteria *Bacillus thuringiensis* var. *israelensis* (*Bti*) and *B. sphaericus*, and the bacterial product spinosad. Given the low rainfall for much of the year, MMCD only applied larvicide to 144,856 acres, which is more than in 2022 (129,497 acres treated), but below the yearly average from 2017-2021. A cumulative total of 317,239 catch basin treatments were made to control WNV vectors, which was up from 301,813 in 2022. In 2023, slightly more adult treatments were made (1,863 acres) than in 2022 (1,696 acres), but total adult treatments remained below average for the third consecutive year.

To control black flies in the metro area, MMCD made 88 small stream treatments and 33 large river treatments with liquid *Bti* when the larval population of the target species met the treatment threshold. The average number of adult black flies per sweep in 2023 was 0.90, which was higher than 2022 (0.57), but lower than the 1996-2022 average of 1.21. This was the third year that *Simulium tuberosum* larval populations were treated in small streams, responding to public concern from high populations of this species in recent years. In 2024, the District plans to continue monitoring *S. tuberosum* larval and adult populations to better understand its distribution, abundance, and life history.

Product and Equipment Testing

Evaluation of products, equipment, and processes is an important part of our program. In 2023, staff found that VectoBac® G *Bti* applied by helicopter at 8 lb/acre produced improved control of spring *Aedes* and *Ae. vexans* than the 5 lb/acre applications in 2022. In 2024, staff plan to collect more data to continue to evaluate the efficacy of treatments.

MMCD Technical Services staff evaluated the use of a LiDAR system which may prove beneficial in habitat topographical mapping.

Evaluation of extended duration products like Natular® G30, CENSOR® G, and Duplex™-G was limited due to drought conditions in 2023. Staff plans to continue to evaluate these products in 2024.

New Technologies, Data Management, and Public Information

The drone program continues to expand and in 2023 MMCD made five times the number of larvicide treatments compared to 2022. In 2023, staff treated 1,227 sites using Altosid® P35 and VectoLex® which was significantly more than the 257 sites treated in 2022. The number of acres treated by drone also expanded to 1,633.55 in 2023, which was up from 343 in 2022. Staff continued to use drones for aerial photography and site scouting.

MMCD made big improvements to District mapping abilities in 2023 by rebuilding the Mobile Map for field data and building a new catch basin treatment map and data system for mobile use. Staff also finished the transition of desktop mapping software to QGIS and continued a major upgrade of the field data system software interface.

Public reports of adult mosquito annoyance reached their highest level since 2016 due to high mosquito populations in late May and early June. Calls to request tire recycling reached a 10-year high with 534 calls from residents in 2023. MMCD attended a number of public events and presented to schools and community groups throughout the year.

Chapter 1 *Mosquito Surveillance*

2023 Highlights

- The metro area received over 90 inches of snow, which was 36.3 inches above normal
- The winter received above normal precipitation; beginning in mid-May, dry to drought conditions prevailed
- There was one large spring snowmelt brood (largest in history). There were zero large summer floodwater broods, 2 medium broods, and 4 small broods
- Identified 12,133 larval and 7,240 adult samples (excluding NJ trap samples)
- Adult spring *Aedes* emerged May 16 and peaked May 31
- The major summer *Aedes* emergence was May 31 and peaked June 6 -- only large peak of the summer
- *Cq. perturbans* were detected May 31. Peak levels occurred over several weeks from June 21-July 11, well below the 23-yr average
- Predicted catch rate for *Cq. perturbans* for 2023 was 18.1/trap. The actual value was 14.7/trap. The prediction for 2024 is 19.2 per trap

2024 Plans

- Evaluate Biogents BG Pro vs current CO_2 trap
- Analyze Long-Term CO_2 traps (species richness)
- Publish a paper on the mosquito fauna of the Twin Cities metropolitan area

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-three known mosquito species occur in Minnesota, although one, *Aedes albopictus*, is reintroduced yearly. All have a variety of host preferences. Forty-nine 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 common species) begin hatching in late April and early May in response to rainfall and warmer temperatures. Adults can lay multiple egg batches and live on average two weeks. *Coquillettidia perturbans* (the cattail mosquito) develops in cattail marshes. There is one emergence, which begins in early June, peaking around the Fourth of July. Disease vectors include *Aedes triseriatus*, *Culiseta melanura*, and *Culex pipiens*, *Cx. restuans*, *Cx. salinarius*, and *Cx. tarsalis*. Adults are evident in early summer, and they can produce multiple generations per year. Appendix A contains a species list and detailed descriptions of the mosquitoes occurring in the District.

2023 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 60 years ago. These data are shared with the Minnesota State Climatologist's office for analysis. Currently, rain gauge data is entered directly into the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) system to make the measurements available more quickly for each other, the National Weather Service (NWS), and the public. This system has limitations because of the sparse gauge network in some areas of the District.

The NWS River Forecast Center (RFC) creates a 4x4 km grid of precipitation estimates based on a combination of NEXRAD (Next Generation Weather Radar), satellite, and ground rain gauge measures (including MMCD's gauges submitted through CoCoRaHS). This dataset is one of the best sources of timely, high resolution precipitation information available.

Average seasonal rainfall in the District is calculated from May-September using historical MMCD rain data and CoCoRaHS gauges. This time-period is referred to as the 'mosquito season'. Rainfall during the mosquito season (April 30-September 30, 2023) was 14.71 inches – well below the 64-year District average of 19.72 inches. April rainfall can influence adult emergence in May as well. The average precipitation for the weeks of March 26 through September 30, 2023, was 19.91 inches. At the end of September there was a 4.43-inch rain event which increased the season average.

Figure 1.1 shows the sum of daily rainfall averages by week across the District from March 26-September 30, 2023. Weekly average rainfall in excess of one inch occurred five times from May through September. Beginning in mid-May the metro area received little rainfall, and the area was moving into increasingly dry conditions. There were four weeks when rainfall was at the one-inch threshold, but the precipitation was absorbed into the dry ground or by vegetation reducing the amounts that flowed into wetlands. The large rain event is shown at the end of the mosquito season (week of Sept 25, 2023).

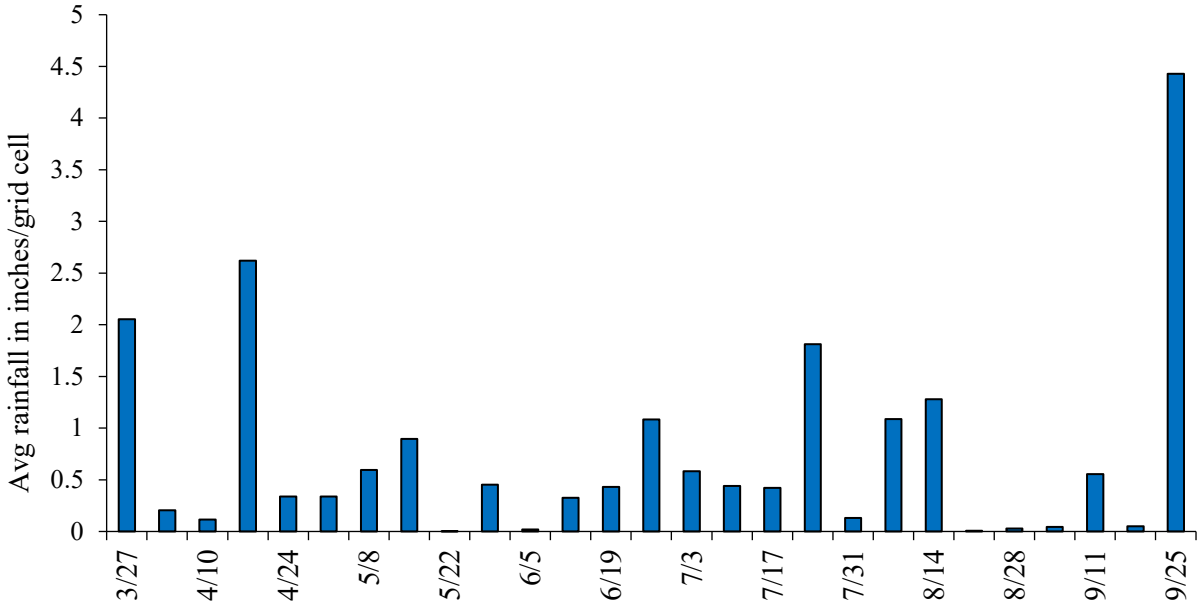


Figure 1.1 Sum of daily rainfall averages per week per grid cell, 2023 (RFC data). Dates represent the Monday of each week.

Typically, spring *Aedes* mosquito larvae develop over a period of months (mid-March to early May), and summer species develop over a period of days (7-10). Water temperature and precipitation amounts influence how quickly larvae develop in sites. The winter/spring of 2022-2023 was about normal. Temperatures in January were 4 degrees above the norm and February was only 0.5 degrees above the norm (Fig. 1.2). March and April were cool; March was 4.3°F below the norm. From May through September, temperatures were above the norm but not remarkably so. Like the previous summer, 2023 was warm; there were 33 days above 90°F. The frost left the ground on April 9, and ice-out on Lake Minnetonka occurred April 19; the average ice-out date is April 13.

The snowfall total for the season was 90.3 inches from November-April 15, which is the third snowiest on record. The Twin Cities normal average snowfall is 54 inches (from 1981-2010). Precipitation in January, February, and March was above the norm (Fig. 1.2). Precipitation in April was 0.5 inches below the norm and, from mid-May onward, very few rain events of significant amounts occurred. In fact, rainfall from May-August was 10 inches below the norm. The large rain event at the end of September and more rains in October brought some relief to the drought; however, precipitation in November and December has been below the norm to finish out 2023. As of December, the District is abnormally dry or experiencing moderate drought (https://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?MN).

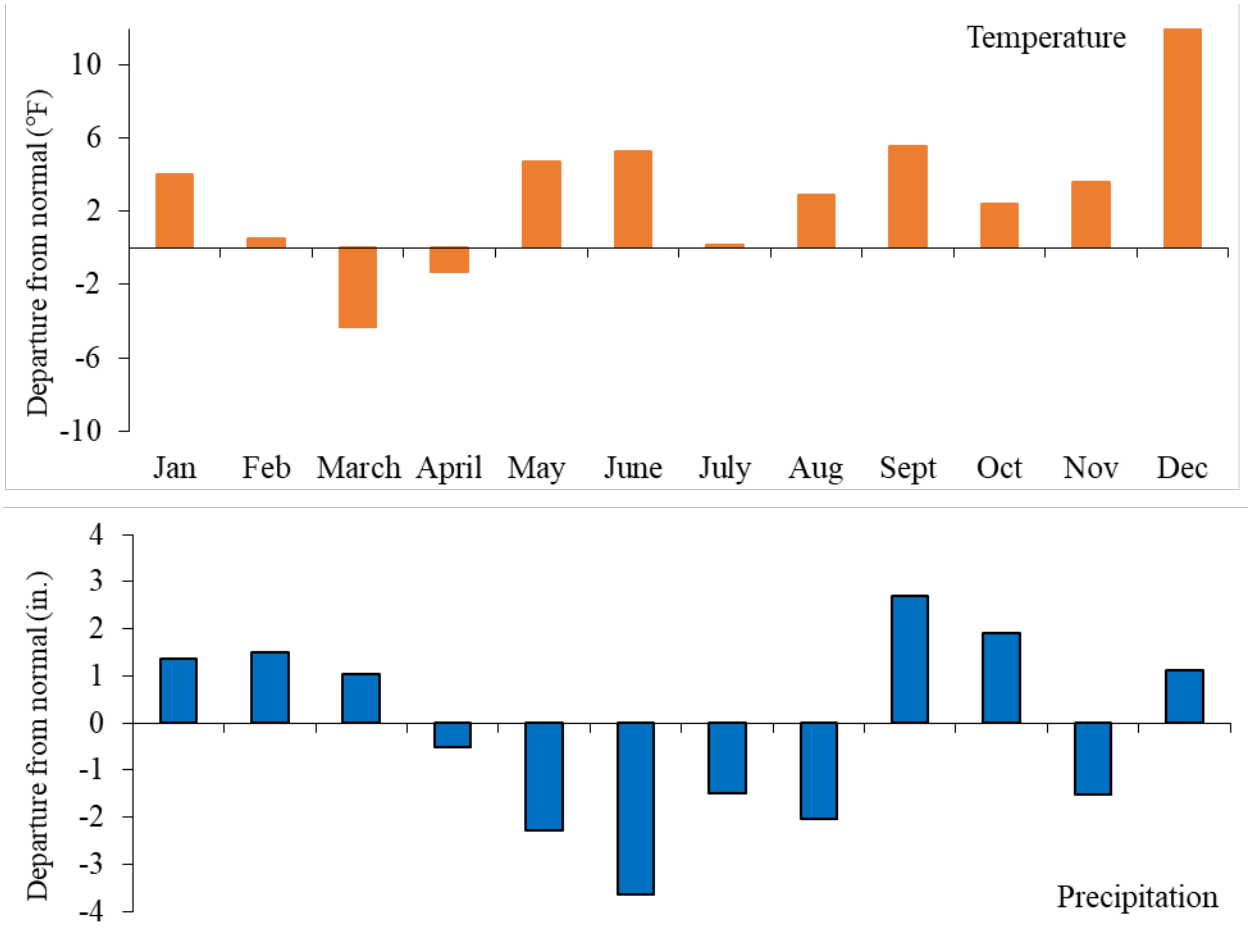


Figure 1.2 Monthly departures from normal for temperature and precipitation January-December 2023 (source: National Weather Service, Twin Cities Station).

Snowmelt and rainfall during March through early May triggered spring *Aedes* and floodwater *Aedes* to hatch. By May 14, the species composition transitioned to floodwater *Aedes*. There were six rain events sufficient to produce floodwater *Aedes* hatches (i.e., broods): there were no large, District-wide events, but there were two medium (weeks of 6/25 and 8/13), and four small broods (weeks of 5/14, 5/28, 7/2, and 7/23), which occurred in localized areas. The actual area affected by rainfall, the amount of rainfall received, and the resultant amount of mosquito production and acreage treated by helicopter determines brood size. Figure 1.3 depicts the geographic distribution and magnitude of weekly rainfall received in the District from March 26-September 16, 2023. Since some weeks had multiple rain events, the cumulative weekly rainfall does not identify individual rain events. Medium to dark gray shading indicates rainfall greater than or equal to one inch, enough to initiate a brood.

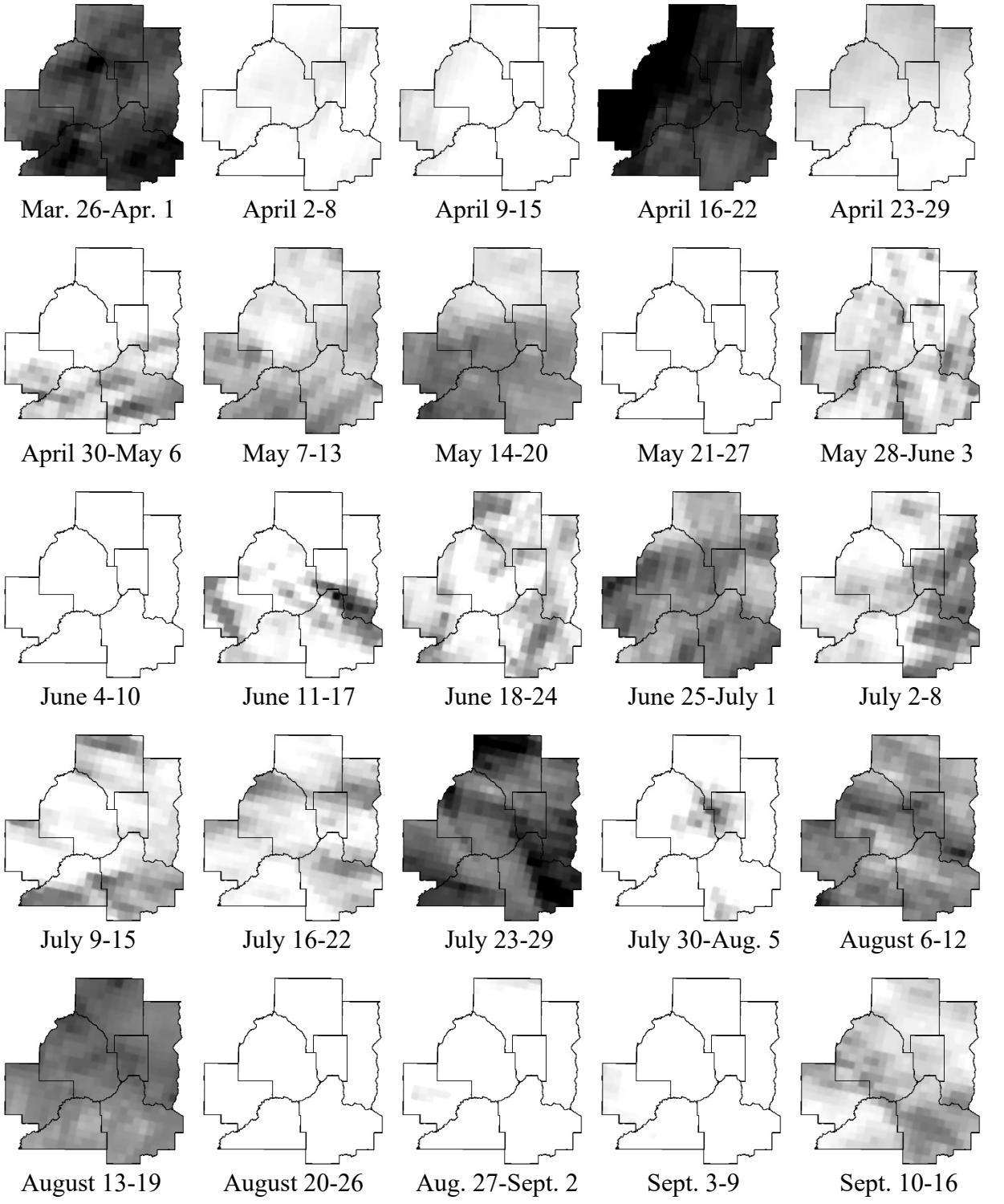


Figure 1.3 Weekly rainfall in inches, 2023. RFC-corrected data using 406 4x4 km grid cells. Inverse distance weighting was the algorithm used for shading maps.

Larval Collections

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

To expedite sample processing for high priority helicopter treatments (air sites), most larvae are identified to genus only, but again in 2023 we identified the spring *Aedes* to species until May 14, when the prevalent larval species were summer floodwater *Aedes*. After that time, we returned to genera level identifications. *Culex* larvae are always identified to species to differentiate vectors. Staff process lower priority samples as time permits and those are identified to species.

In 2023, lab staff identified 12,133 larval samples (Fig. 1.4). The 25-year average is 19,610 larval samples per year. The low number of samples the last four years was related to decreased staffing levels due to the COVID-19 pandemic, and also due to drought conditions experienced during the mosquito season in 2021, 2022, and 2023.

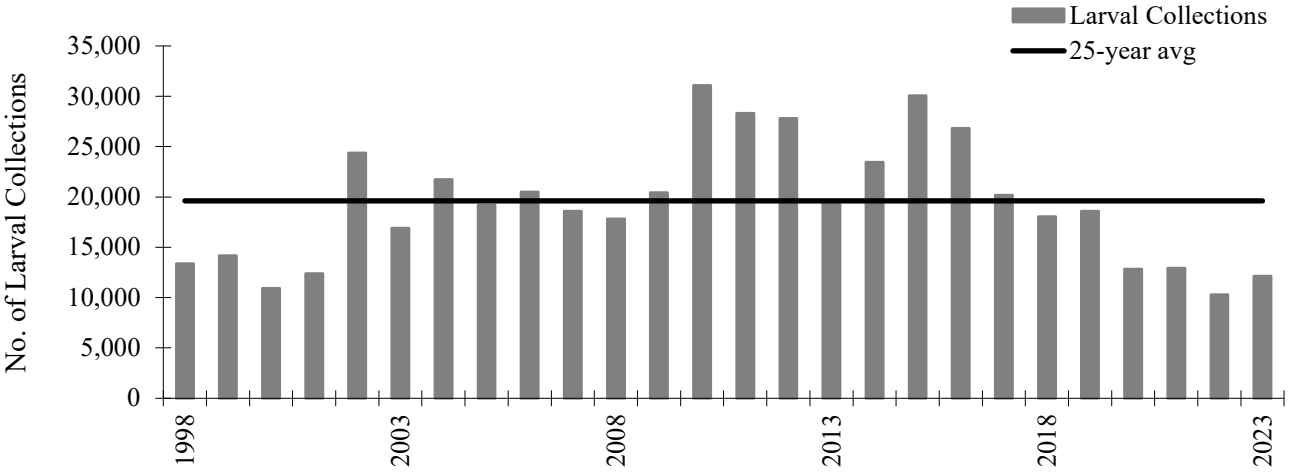


Figure 1.4 Yearly total larval collections, 1998-2023, and 25-year average. Prior to 2015, these totals did not include container samples.

The results of 9,222 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 we also sample 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.

Table 1.1 Percent of samples where larval species occurred in wetland collections by facility and District total, and the District total for structure samples, 2023; the total number of samples processed to species is in parentheses.

	Percent of samples where species occurred by facility							
Species	North (1,734)	East (2,274)	South Rosemount (1,002)	South Jordan (543)	West Plymouth (875)	West Maple Grove (571)	Wetland Total (6,999)	Structures Total (2,223)
Aedes abserratus	2.71	1.50	0.60	0.74	1.37	0.88	1.54	-
aurifer	0.29	0.35	-	-	-	0.35	0.21	-
canadensis	0.40	1.50	2.69	1.47	0.23	0.70	1.17	-
cinereus	15.28	12.84	9.98	17.13	18.51	18.21	14.52	0.49
dorsalis	0.12	0.26	0.30	-	0.46	0.35	0.24	0.09
excrucians	13.21	12.23	10.38	10.50	10.63	13.84	12.00	-
fitchii	2.54	4.53	3.29	0.74	1.49	0.88	2.89	-
flavescens	-	-	-	-	-	-	-	-
hendersoni	-	-	-	-	-	-	-	-
implicatus	0.12	0.48	0.20	-	0.57	0.35	0.31	-
intrudens	-	-	-	-	-	0.18	0.01	-
japonicus	0.12	0.44	0.50	-	0.23	-	0.27	4.09
nigromaculis	-	-	0.30	-	-	-	0.04	0.04
provocans	4.61	1.93	0.80	-	0.11	2.28	2.09	-
punctor	0.75	1.54	-	0.18	1.14	0.53	0.89	-
riparius	0.81	1.32	0.70	0.74	1.26	2.28	1.13	-
spencerii	-	0.04	-	-	-	-	0.01	-
sticticus	3.86	2.37	4.09	1.47	1.71	3.15	2.90	-
stimulans	19.43	16.40	23.65	16.02	15.43	24.69	18.72	0.04
triseriatus	-	0.04	-	-	-	-	0.01	0.76
trivittatus	0.35	1.19	1.40	0.92	0.69	0.70	0.89	0.31
vexans	16.96	23.88	31.24	13.63	16.91	11.21	20.52	4.00
Ae. unidentifiable	20.18	19.17	14.77	17.50	22.17	31.70	20.06	3.15
Anopheles earlei	-	-	-	-	-	-	-	-
punctipennis	3.23	1.93	0.30	1.10	1.26	1.23	1.81	1.39
quadrimaculatus	8.07	3.96	0.60	10.13	1.94	3.15	4.66	0.99
walkeri	0.06	0.04	-	-	-	-	0.03	0.04
An. unidentifiable	15.05	8.53	2.10	9.76	4.34	4.38	8.46	4.50
Culex erraticus	-	-	-	-	-	-	-	-
pipiens	7.84	17.24	7.68	10.87	15.77	15.41	12.72	69.05
restuans	8.77	14.12	10.68	8.84	17.49	11.56	12.10	67.57
salinarius	0.06	-	-	-	0.34	-	0.06	0.04
tarsalis	1.38	0.97	0.80	2.95	1.49	1.40	1.30	1.03
territans	36.79	24.89	9.68	23.76	16.69	17.16	23.92	12.33
Cx. unidentifiable	5.02	7.08	4.09	5.71	7.54	7.01	6.09	57.58
Culiseta inornata	9.40	13.24	32.14	25.23	27.43	13.84	17.75	2.07
melanura	-	-	-	-	-	-	-	-
minnesotae	0.58	0.57	0.30	0.18	1.83	1.05	0.70	-
morsitans	0.06	0.09	0.10	-	0.11	-	0.07	-
Cs. unidentifiable	1.44	1.28	0.40	0.92	3.09	1.93	1.44	0.31
Or. signifera	-	-	-	-	-	-	-	-
Ps. ciliata	-	-	-	-	-	-	-	-
ferox	0.06	-	0.10	-	-	-	0.03	-
horrida	-	-	-	-	-	-	-	-
Ps. unidentifiable	0.06	0.09	0.10	-	0.11	-	0.07	-
Ur. sapphirina	5.48	2.42	0.60	4.79	0.46	1.40	2.77	0.27

The top five most frequently encountered species in wetland samples were *Culex territans* (23.9%), *Aedes vexans* (20.5%), *Ae. stimulans* (18.7%), *Culiseta inornata* (17.8%), and *Ae. cinereus* (14.5%) (Table 1.1). Early season snowmelt and rain resulted in *Ae. vexans* and *Ae. cinereus* being collected frequently; permanent water species such as *Cx. territans* were collected more frequently as their habitats were less likely to dry down during the summer drought conditions. The most frequently encountered species in stormwater structures were *Cx. pipiens* (69.1%) and *Cx. restuans* (67.6%) (Table 1.1).

Adult Mosquito Collections

The District uses a variety of adult surveillance strategies 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, incandescent 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 use olfactory bait to attract and capture egg laying *Culex* and *Aedes* species. BG sentinel traps use an attractant lure that mimics human odor to target invasive *Aedes* species, including the annually reintroduced *Ae. albopictus*, and are placed in areas at high risk for species introductions.

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 (West Nile virus-WNV), and eastern equine encephalitis (EEE) testing]. Although a few locations are located beyond District boundaries, only data from locations within are included in the analysis. This network of sweep net and CO_2 trap collections was run weekly from May 15-September 11, and was discontinued early due to lack of mosquitoes.

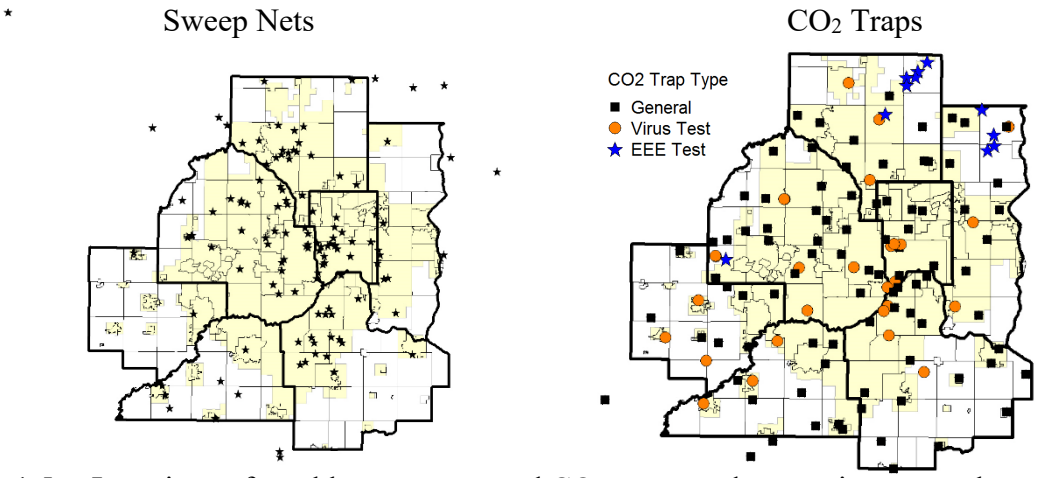


Figure 1.5 Locations of weekly sweep net and CO_2 traps used to monitor general mosquito levels (squares) and disease vectors (circles =WNV and stars= EEE), 2023.

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

Sweep Net The District uses weekly sweep net collections to monitor mosquito annoyance to humans during the peak mosquito activity period, which is 35-40 minutes after sunset for most mosquito species. There were 124 sweep locations (110 inside District boundaries and 14 outside) in 2023, and the number of collectors inside the District varied from 43-90 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 (i.e., *Cx. pipiens*, *Cx. restuans*, *Cx. salinarius*, and *Cx. tarsalis*).

Staff made 1,330 collections containing 2,213 mosquitoes in 2023. Table 1.2 shows the average number of the different species groups collected per sweep net collection. Summer *Aedes* populations were higher than the previous four years, while *Cq. perturbans* remained at very low levels (Table 1.2). Record levels of spring *Aedes* occurred in 2023 due to the record snowmelt in 2023; their levels were five times higher than the 23-year average. *Culex tarsalis* populations were typically low.

Table 1.2 Average number of mosquitoes collected per evening sweep net collection within the District, 2019-2023 and 23-year average, 2000-2022 (± 1 SE)

Year	Summer *Aedes*[1]	*Cq. perturbans*	Spring *Aedes*[2]	*Cx. tarsalis*
2019	0.55	0.14	0.09	0.003
2020	0.53	0.48	0.02	0.001
2021	0.13	0.07	0.01	0.002
2022	0.24	0.02	0.05	0.000
2023	0.93	0.09	0.51	0.002
23-yr Avg.	1.51 (±0.28)	0.31 (±0.05)	0.10 (±0.03)	0.007 (±0.001)

[1] The summer *Aedes* designation can include any combination of the following species: *Ae. atropalpus, Ae. canadensis, Ae. cinereus, Ae. dorsalis, Ae. nigromaculis, Ae. sticticus, Ae. triseriatus, Ae. trivittatus, Ae. vexans, Ae. hendersoni, Ae. albopictus, Ae. japonicus,* and unidentifiable *Aedes.*

[2] The spring *Aedes* designation can include any combination of the following species: *Aedes abserratus, Ae. aurifer, Ae. euedes, Ae. campestris, Ae. communis, Ae. diantaeus, Ae. excrucians, Ae. fitchii, Ae. flavescens, Ae. implicatus, Ae. intrudens, Ae. pionips, Ae. punctor, Ae. riparius, Ae. spencerii, Ae. stimulans,* and *Ae. provocans.*

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 ~25 feet high in the tree canopy to monitor bird biting species (i.e., *Culex* spp.). The treatment threshold is 130 nuisance mosquitoes per CO_2 trap. Vector species thresholds are discussed in Chapter 4.

In 2023, we placed 138 traps at 127 locations (11 of these locations had low traps paired with elevated traps) to allow maximum coverage of the District (Figure 1.5). Three traps were outside District boundaries, at employee homes, and were not included in these analyses. The "General" trap type locations are used to monitor non-vector mosquitoes. There are 48 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 2,142 District low CO_2 trap collections taken contained 299,801 mosquitoes in 2023. The total number of traps operated weekly varied from 114-123. The average number of mosquitoes detected in CO_2 traps is found in Table 1.3. Summer *Aedes*, our most abundant species, increased from 2022, but still was much lower than the 23-year average. Three years of drought have affected *Cq. perturbans* populations which were very low again in 2023, and well below the 23-year average. Spring *Aedes* levels were the highest they've ever been – over 3.5 times more than the 23-year average. *Culex tarsalis* numbers were very low again in 2023.

Table 1.3 Average numbers of mosquitoes collected in CO_2 traps within the District, 2019-2023 and 23-year average, 2000-2022 (± 1 SE)

Year	Summer *Aedes*[1]	*Cq. perturbans*	Spring *Aedes*[2]	*Cx. tarsalis*
2019	160.1	66.1	6.5	0.7
2020	182.4	127.3	3.5	0.2
2021	35.0	28.3	2.7	1.3
2022	53.3	13.9	8.3	0.4
2023	81.9	14.7	32.4	0.3
23-yr Avg.	189.1 (±25.6)	53.9 (±7.4)	6.2 (±0.9)	1.6 (±0.3)

[1] The summer *Aedes* designation can include any combination of the following species: *Ae. atropalpus, Ae. canadensis, Ae. cinereus, Ae. dorsalis, Ae. nigromaculis, Ae. sticticus, Ae. triseriatus, Ae. trivittatus, Ae. vexans, Ae. hendersoni, Ae. albopictus, Ae. japonicus,* and unidentifiable *Aedes.*

[2] The spring *Aedes* designation can include any combination of the following species: *Aedes abserratus, Ae. aurifer, Ae. euedes, Ae. campestris, Ae. communis, Ae. diantaeus, Ae. excrucians, Ae. fitchii, Ae. flavescens, Ae. implicatus, Ae. intrudens, Ae. pionips, Ae. punctor, Ae. riparius, Ae. spencerii, Ae. stimulans,* and *Ae. provocans.*

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 close by and may not reflect actual densities of mosquitoes. Priority area 1 (P1) receives full larval control. A full description of priority areas is in Chapter 4: Mosquito Control.

Spring *Aedes* populations were first detected the week of May 15 in the northern part of the District, the first night of sampling (Figure 1.6). The highest levels were detected in northeastern Anoka and Washington counties on May 30. A large emergence was detected in northern Hennepin County (Rogers, Dayton) along the western border of the District on June 5.

The first detections of summer *Aedes* occurred in the first sampling week and the highest and most widespread mosquito levels occurred the week of June 5 (Fig. 1.7). Small, localized emergences occurred thereafter and there were no widespread rain events sufficient to produce large broods across the District after mid-May in 2023.

Coquillettidia perturbans was first detected in Washington County the week of May 30 (Figure 1.8). Emergence increased weekly thereafter. Highest levels occurred during June 20-July 10. Populations steadily declined thereafter. Highest levels occurred outside of P1 on the outer borders of the District.

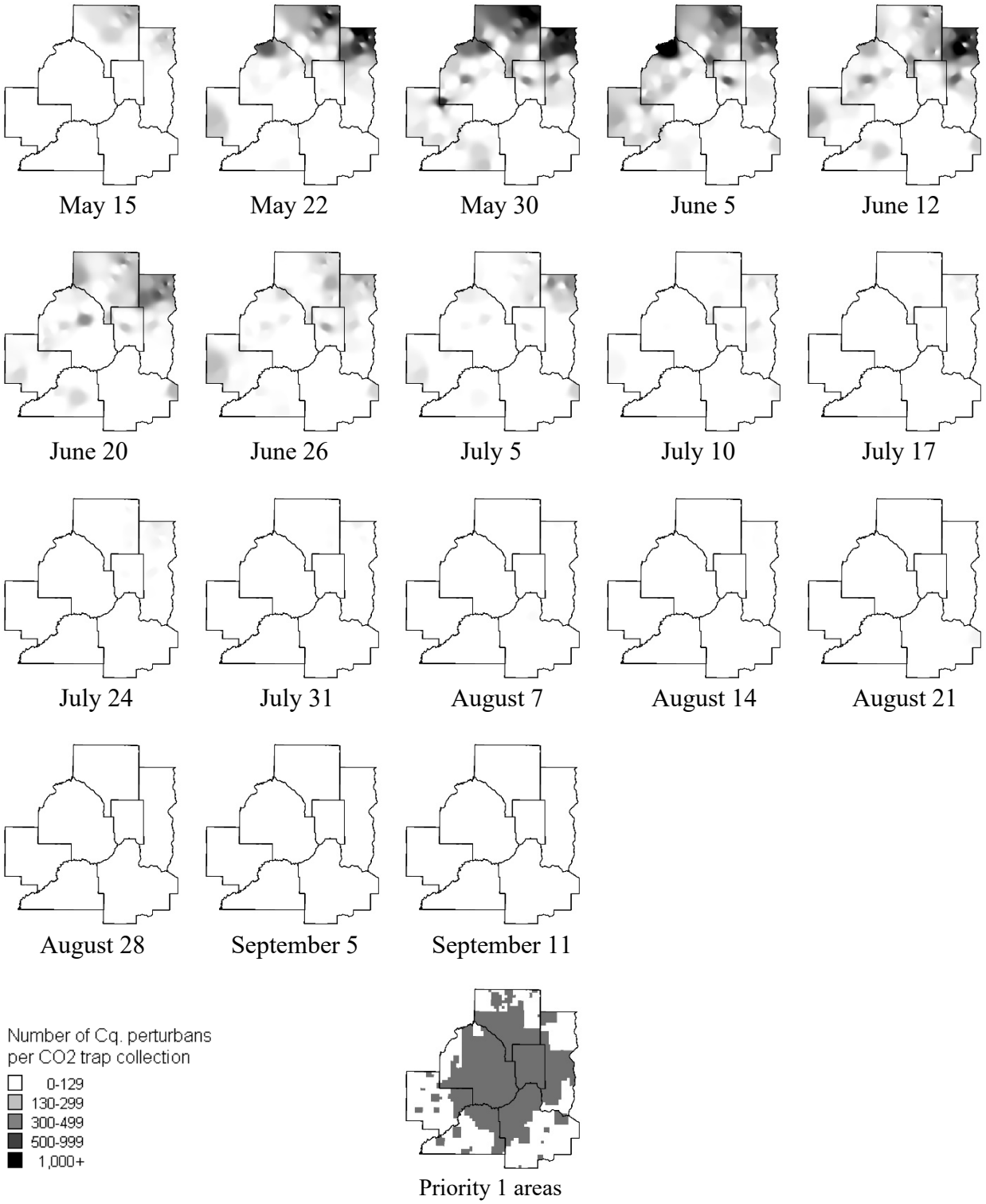


Figure 1.6 Number of spring *Aedes* in District low (5 ft) CO_2 trap collections, 2023. The number of traps operated per night varied from 114-123. Inverse distance weighting was the algorithm used for shading maps. Treatment threshold is >130 mosquitoes/trap night. Priority 1 area map for reference.

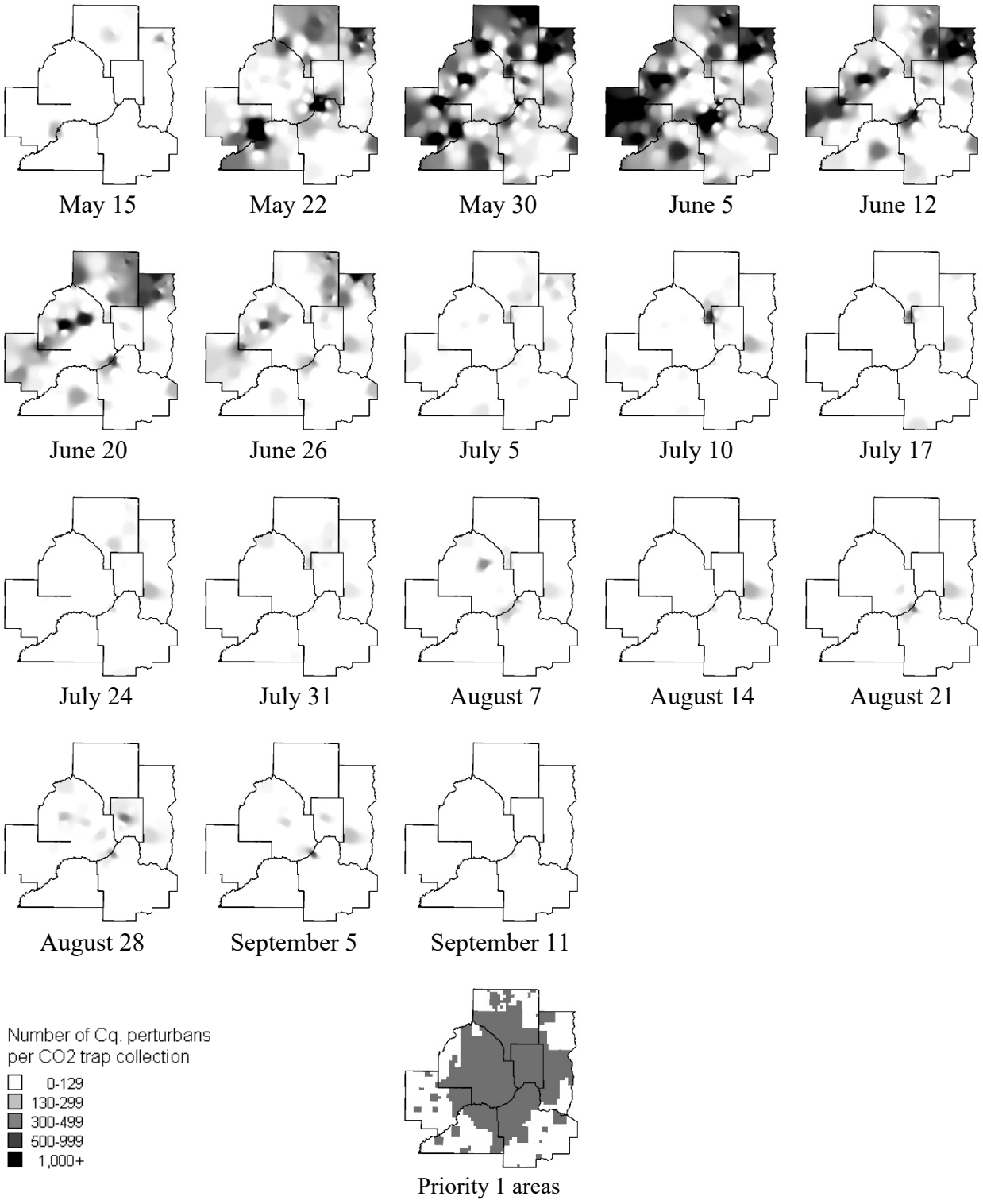


Figure 1.7 Number of summer *Aedes* in District low (5 ft) CO_2 trap collections, 2023. The number of traps operated per night varied from 114-123. Inverse distance weighting was the algorithm used for shading maps. Treatment threshold is >130 mosquitoes/trap night. Priority 1 area map for reference.

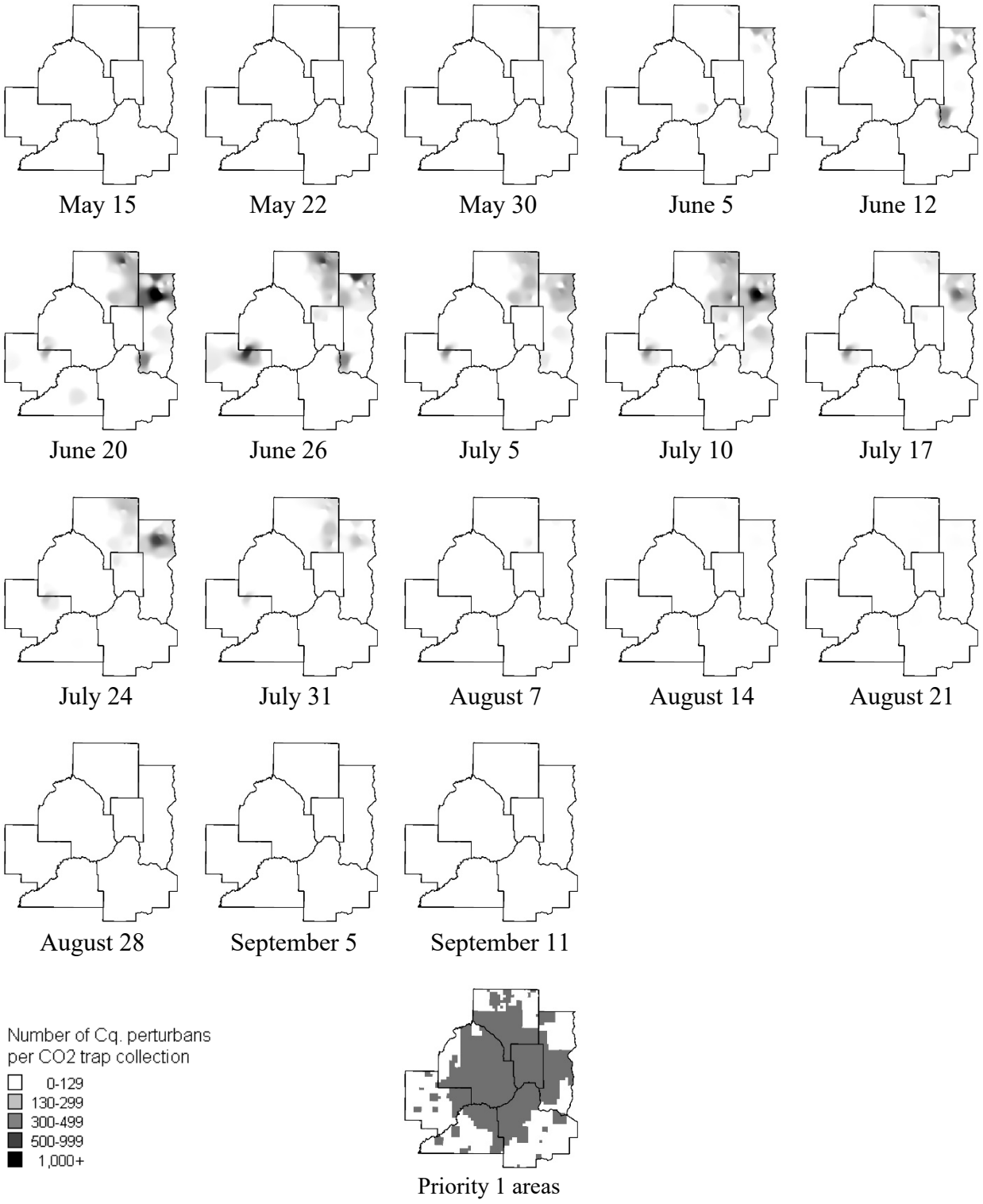


Figure 1.8 Number of *Cq. perturbans* in District low (5 ft) CO_2 trap collections, 2023. The number of traps operated per night varied from 114-123. Inverse distance weighting was the algorithm used for shading maps. Treatment threshold is >130 mosquitoes/trap night. Priority 1 area map for reference.

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 2023, sampling with sweep nets and CO_2 traps started May 15. Temperatures at the time of sweep netting were well above the minimum mosquito flight threshold all season.

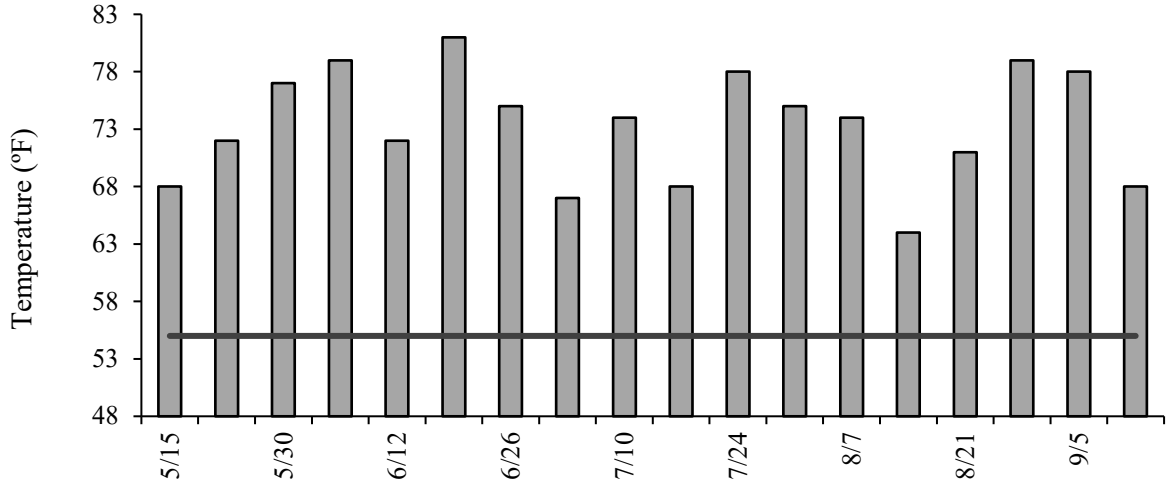


Figure 1.9 Temperature at 9:00 p.m. on actual dates of Monday night surveillance, 2023 (source: National Weather Service, Twin Cities Station). The black horizonal line indicates the mosquito flight threshold, 55°F.

Figures 1.10 and 1.11 show the seasonal distribution of the three major groups of mosquitoes detected in sweep nets and CO_2 traps. Sweep netting detected the adult spring *Aedes* emergence on the season's first night of surveillance, May 15; populations peaked on May 30 far above the 23-year average (Fig. 1.10). High levels remained for the next three weeks and by June 26 populations were low, nearing the 23-year average. Highest captures in CO_2 traps also occurred the night of May 30, and populations detected in CO_2 traps were above the 23-year average until July 10 (Fig. 1.11).

Summer *Aedes* were first detected in sweep net and CO_2 traps the night of May 15 and peaked on the night of May 30 (Fig. 1.10 and Fig. 1.11). The summer *Aedes* in sweep samples were above the 23-year average from May to mid-June and quickly declined thereafter. The highest levels in CO_2 traps were seen on May 31, above the 23-year average (Fig 1.11). Populations quickly declined after that and there were no broods to speak of for the rest of the summer.

Coquillettidia perturbans was initially detected May 30 in sweep nets and CO_2 traps. The peak in sweep nets occurred on July 10 and the last *Cq. perturbans* was collected on August 14 (Fig. 1.10). The population was well below the 23-year average (Fig. 1.10). Highest levels in CO_2 traps occurred from June 21-July 11 (Fig. 1.11) and were below the 23-year average the entire year.

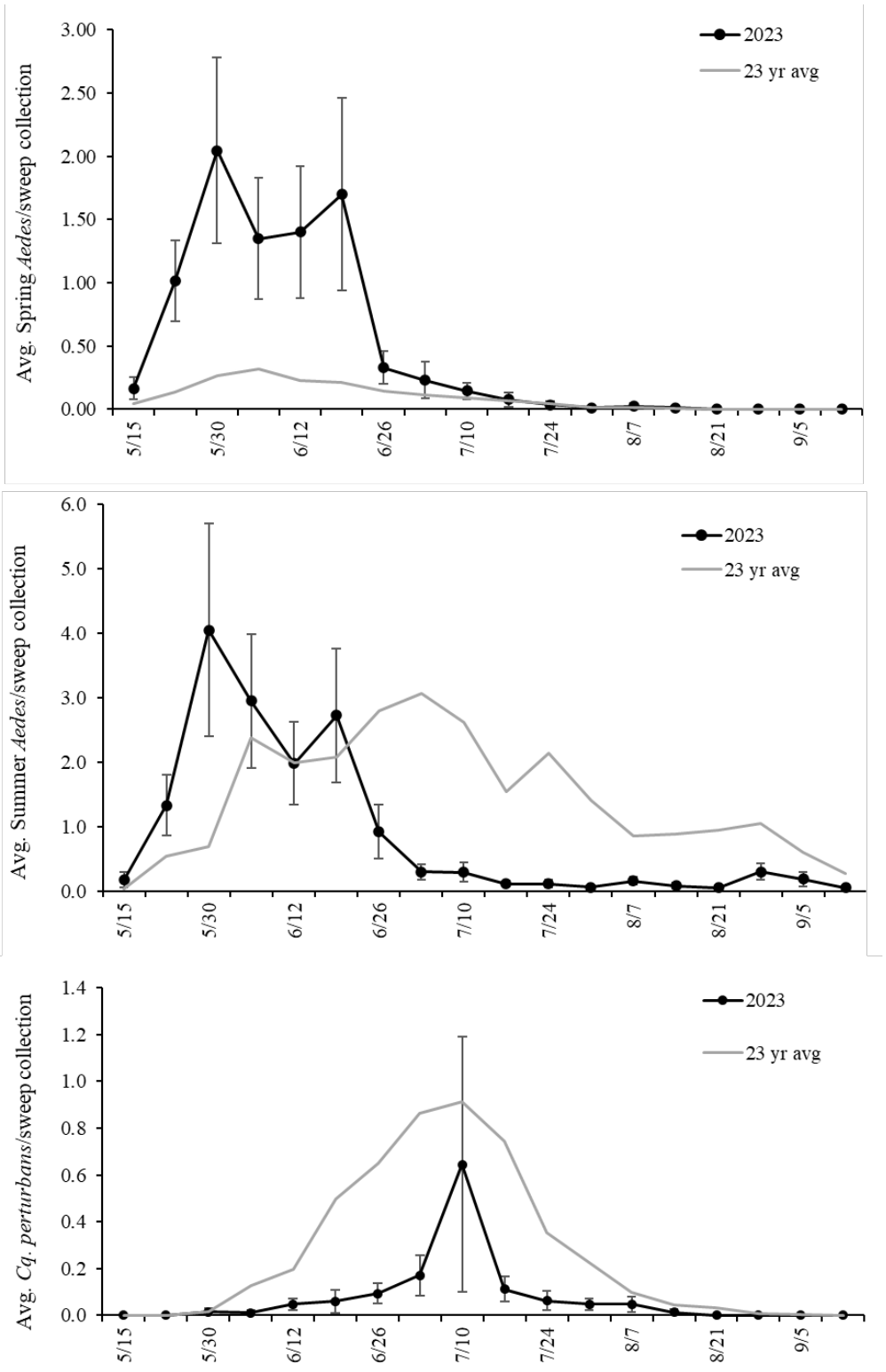


Figure 1.10 Average number of spring *Aedes*, summer *Aedes*, and *Cq. perturbans* per sweep net collection, 2023 vs. 23-year average. Dates are the Mondays of each week. Error bars equal $\pm$ 1 standard error of the mean.

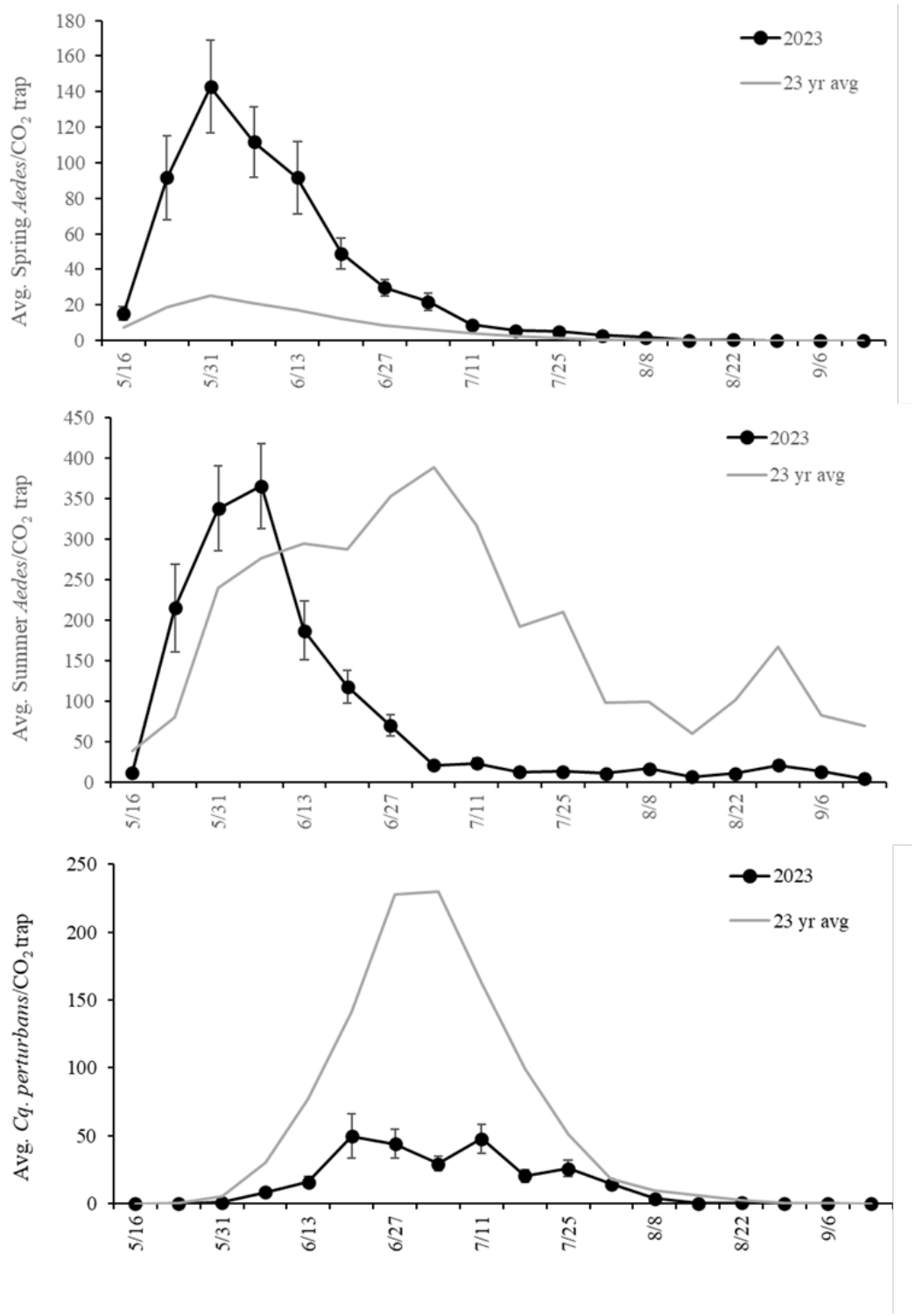


Figure 1.11 Average number of spring *Aedes*, summer *Aedes*, and *Cq. perturbans* per CO_2 trap, 2023 vs. 23-year average. Dates are the Tuesday of each week, except when sampling falls on a holiday. Error bars equal $\pm$ 1 standard error of the mean.

The difference in mosquito levels in priority zones (P1 = full larval treatment and P2 = limited or no larval treatment) is shown in Figure 1.12. Mosquito levels were low in P1, as expected. Summer *Aedes* was the most abundant species group in P1 and P2. Spring *Aedes* were highest in P2 as was *Cq. perturbans*.

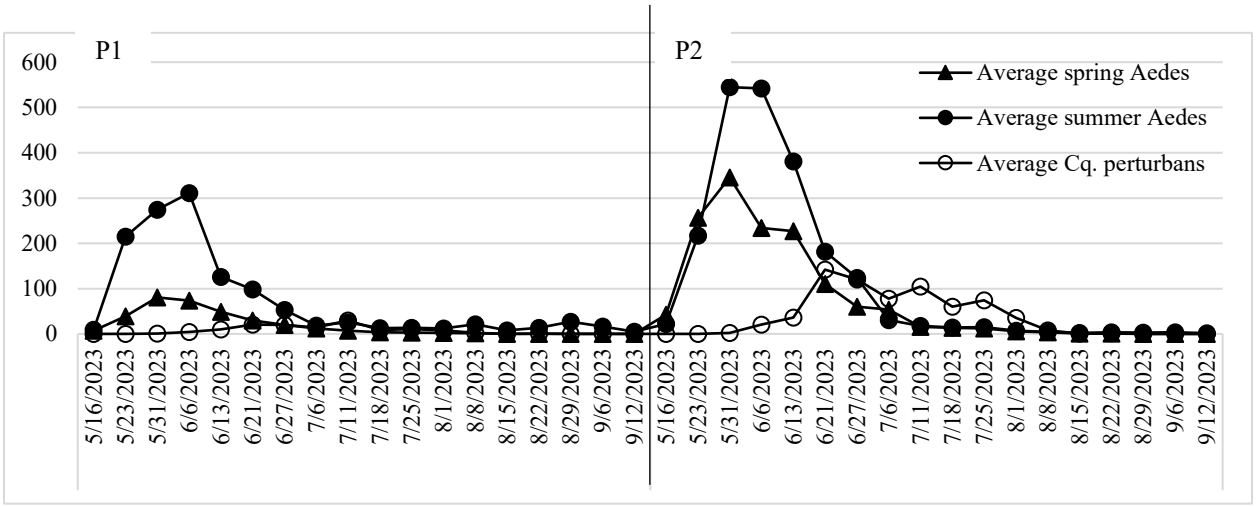


Figure 1.12 Average number of spring *Aedes*, summer *Aedes*, and *Cq. perturbans* per CO_2 trap, 2023 in P1 and P2.

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 incandescent 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, 13, and 16 have been in the same cities since 1965. The CA1 trap started in 1991.

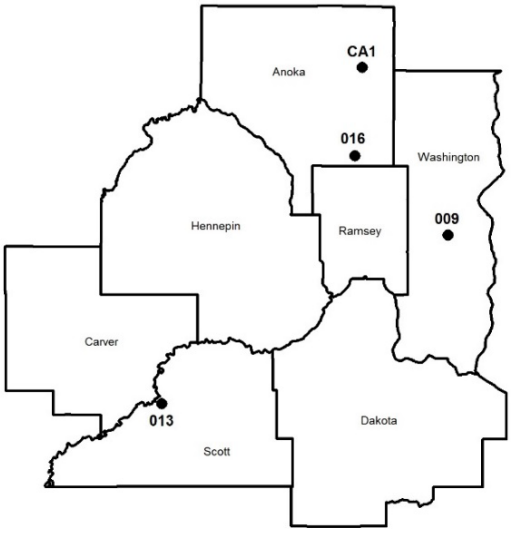


Figure 1.13 NJ light trap locations, 2023.

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 three traps run since 1965 are shown in Appendix B.

The top five most abundant species collected were *Ae. abserratus/punctor* (27.24% of all female mosquitoes captured – includes *Ae. abserratus*, *Ae. punctor*, and unidentifiable *abserratus/punctor*), *Ae. cinereus* (19.43%), *Cq. perturbans* (15.14%), *An. quadrimaculatus* (8.53%), and *Ae. vexans* (4.74%), (Table 1.4). The Carlos Avery trap (CA1) collected 81.1% of all females trapped followed by Lino Lakes (10.8%, Trap 16), Lake Elmo (5.0%, Trap 9), and Jordan (3.1%, Trap 13). Unfortunately, the fan in the Carlos Avery trap was clogged with many insects during the peak *Cq. perturbans* emergence time (end of June-mid-July), and the totals for *Cq. perturbans* are most likely underrepresented.

In Trap 9, located in Lake Elmo, Washington County, *An. quadrimaculatus, Ae. vexans*, and *Cq. perturbans* were the most abundant species. As is typical under drought conditions, the permanent water species, such as *An. quadrimaculatus*, were more abundant than the floodwater species, which rely on rainfall for their eggs to hatch.

Trap 13 is located in Jordan, Scott County. The trapping location is adjacent to a river floodplain with nearby cropland in a rural landscape. The most abundant species collected were *An. quadrimaculatus*, *Ae. sticticus*, and *Ae. vexans*. *Aedes sticticus* and *Ae. vexans* hatched because of melted snowpack and spring rains.

Trap 16 is located in Lino Lakes, Anoka County. The most abundant species collected in this trap was *An. quadrimaculatus*, *Ae. vexans*, and *Ae. cinereus.*

CA1, located in the northern part of the District in Columbus, Anoka County, has a variety of mosquito habitats including ephemeral spring woodland pools, cattail marshes, and many other types of habitats from permanent to temporary marshes and spruce-tamarack bogs. Consequently, this location has a diverse mosquito fauna. The species captured most frequently in CA1 were *Ae. abserratus/punctor, Ae. cinereus,* and *Cq. perturbans.*

Table 1.4 Total numbers and frequency of occurrence for each species collected in New Jersey light traps, May 7-September 23, 2023

	Trap Code, Location, and Number of Collections				Summary Statistics		
	9 Lake Elmo	13 Jordan Office	16 Lino Lakes	CA1 Carlos Avery	Total Collected	% Female	Avg per
Species	132	140	131	114	517	Total	Night
Ae. abserratus	0	0	6	1181	1,187	7.10%	2.296
atropalpus	0	0	0	0	0	0.00%	0.000
aurifer	0	0	0	12	12	0.07%	0.023
canadensis	1	0	0	26	27	0.16%	0.052
cinereus	6	13	123	3,107	3,249	19.43%	6.284
diantaeus	0	0	0	0	0	0.00%	0.000
dorsalis	0	0	1	4	5	0.03%	0.010
excrucians	4	6	7	503	520	3.11%	1.006
fitchii	0	1	1	1	3	0.02%	0.006
hendersoni	0	0	0	0	0	0.00%	0.000
implicatus	0	0	0	0	0	0.00%	0.000
japonicus	2	0	8	0	10	0.06%	0.019
nigromaculus	0	0	0	0	0	0.00%	0.000
punctor	0	0	5	560	565	3.38%	1.093
riparius	0	0	0	0	0	0.00%	0.000
spencerii	0	0	0	0	0	0.00%	0.000
sticticus	2	129	1	162	294	1.76%	0.569
stimulans	1	1	5	522	529	3.16%	1.023
provocans	0	0	1	24	25	0.15%	0.048
triseriatus	2	1	1	1	5	0.03%	0.010
trivittatus	1	0	3	70	74	0.44%	0.143
vexans	161	83	235	313	792	4.74%	1.532
abserratus/punctor	2	1	39	2,761	2,803	16.76%	5.422
Aedes unidentifiable	11	4	7	325	347	2.08%	0.671
Spring *Aedes* unident.	13	0	14	509	536	3.21%	1.037
Summer *Aedes* unident.	1	1	0	2	4	0.02%	0.008
An. barberi	0	0	0	0	0	0.00%	0.000
earlei	0	0	0	0	0	0.00%	0.000
punctipennis	9	12	11	49	81	0.48%	0.157
quadrimaculatus	196	135	786	309	1,426	8.53%	2.758
walkeri	0	15	7	235	257	1.54%	0.497
An. unidentifiable	185	41	202	317	745	4.46%	1.441
Cx. erraticus	0	0	0	0	0	0.00%	0.000
pipiens	2	1	9	1	13	0.08%	0.025
restuans	43	4	72	17	136	0.81%	0.263
salinarius	0	0	0	1	1	0.01%	0.002
tarsalis	5	14	8	3	30	0.18%	0.058
territans	7	2	8	18	35	0.21%	0.068
Cx. unidentifiable	10	1	8	3	22	0.13%	0.043
Cx. pipiens/restuans	61	9	53	13	136	0.81%	0.263
Cs. inornata	15	17	17	11	60	0.36%	0.116
melanura	0	0	2	0	2	0.01%	0.004
minnesotae	0	0	40	52	92	0.55%	0.178
morsitans	0	0	0	7	7	0.04%	0.014
Cs. unidentifiable	0	0	3	12	15	0.09%	0.029
Cq. perturbans	91	11	97	2,333	2,532	15.14%	4.897
Or. signifera	0	0	0	0	0	0.00%	0.000
Ps. ferox	0	0	0	0	0	0.00%	0.000
horrida	0	0	0	0	0	0.00%	0.000
Ps. unidentifiable	0	0	0	0	0	0.00%	0.000
Ur. sapphirina	4	6	23	15	48	0.29%	0.093
Unidentifiable	5	2	11	78	96	0.57%	0.186
Female Total	840	510	1,814	13,557	16,721	100.00%	32.342
Male Total	273	273	646	22,659	23,851		
Grand Total	1,113	783	2,460	36,216	40,572		

Long-term CO_2 Trap Network

In 2021, we began identifying all adult mosquitoes from randomly selected Monday Night Surveillance Network traps. The goal was to augment the information obtained in the New Jersey light traps. The rationale and trap locations are discussed in previous TAB reports (2021, 2022). The designated traps are shown in Table 1.5 and Figure 1.14 shows the selected trap locations in the regions of the District. Full species identifications for the 15 traps are in Appendix C.

Table 1.5 CO_2 traps used for long-term study, by region

West Region	South Region	Northeast Region
C013 – Watertown	D063 – Thompson Co. Pk	A120 – (v) Ajawah EEE
H625 – Ft. Snelling Golf Course*	D181 – Miesville	A183 – Innsbruck Park
H284 – Dayton	DSR4 – Eureka (Rice Lk)	E001 – Stillwater
H291 – Eden Prairie	S139 – Credit River	E004 – Forest Lake
H566 – Eagle Ridge	S154 – (v) Jackson Town Hall	SF02 – (v) Grandstand

*The Ft. Snelling Golf Course trap (H625) replaced the Post Road low trap (H157) in 2022 and is located less than 1 mile away

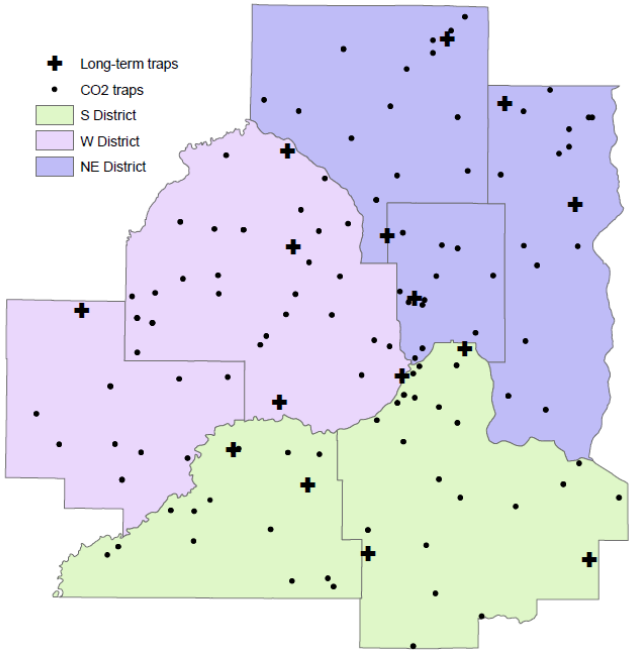


Figure 1.14 Locations of 15 traps selected for long-term CO_2 trap full species level identifications. Green shading is South, lavender shading is West, and purple shading is Northeast.

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 attached to cattail roots, and adults emerge the following June-July, typically peaking around

July Fourth. Adult populations are influenced by rainfall amounts from the previous year. Higher *Cq. perturbans* captures in CO_2 traps occurred (2003, 2011, 2017, and 2020) following years with above normal rainfall amounts (Figure 1.15). A model developed by Dr. Roger Moon (University of MN) is used to predict *Cq. perturbans* in the coming year based on the number of adults collected and the average weekly total rainfall in the previous year.

The predicted catch rate in 2023 was 18.1 *Cq. perturbans* per CO_2 trap, but the actual rate was 14.6 (Figure 1.15). The predicted number of *Cq. perturbans* collected per CO_2 trap in 2024 is 19.2. This model explains ~80% of the variation in predicted *Cq. perturbans* abundance (adjusted R-squared = 0.796). However, because this model is dependent on the amount of rainfall and we received an astounding 4.5 inches of rain the last week of September, the prediction estimate would be only 10.0 *Cq. perturbans* per trap if we exclude that single rainfall event from the model. The prediction helps identify population trends for the coming year, and larval dips confirm presence and treatment locations.

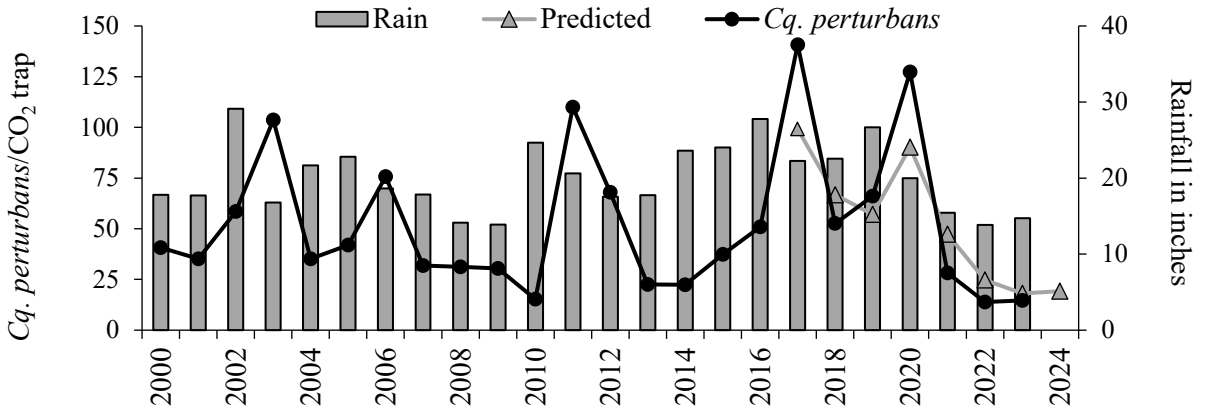


Figure 1.15 Average seasonal rainfall per gauge, average number of *Coquillettidia perturbans* in CO_2 traps, 2000-2023, and predicted amounts for 2017 and beyond.

Rare Detections

With our Monday Night Network, we monitor other species which are considered uncommon or rare in Minnesota. *Culex erraticus*, *An. quadrimaculatus*, and *Psorophora* species have experienced significant changes in populations in recent years. In 2023, we analyzed their occurrences (number of times collected) and have assigned numerical values for very rare (0-9), rare (10-99), uncommon (100-999), common (1,000-9,999), and ubiquitous (>10,000). After that analysis *Culex erraticus, Psorophora ferox*, and *Ps. horrida*, are now in the uncommon category. In 2023, populations of *Cx. erraticus* and *Psorophora* species were lower than the previous two years (Figs 1.16 and 1.17, respectively).

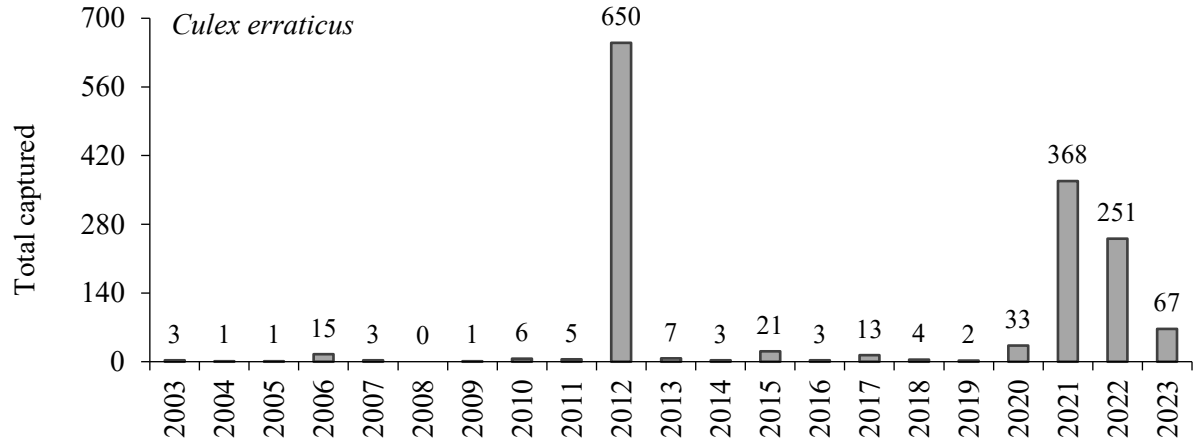


Figure 1.16 Total yearly *Culex erraticus* collected from Monday Night CO_2 traps (low, high, and any outside District), 2003-2023.

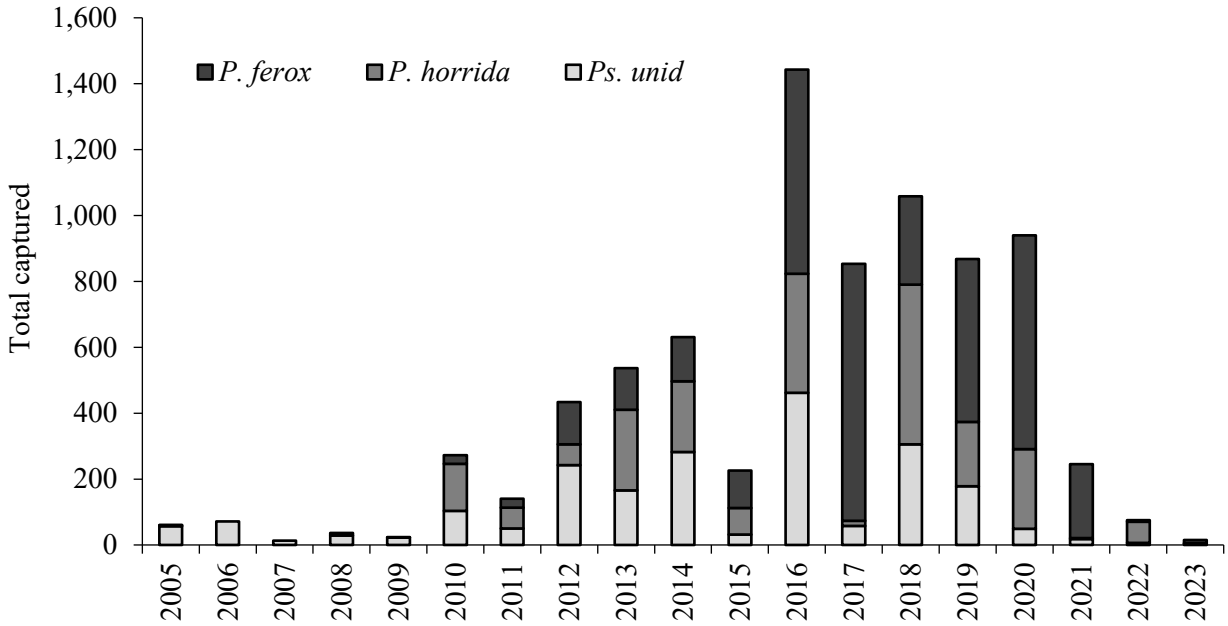


Figure 1.17 Total yearly *Ps. ferox, Ps. horrida,* and *Ps.* unid (unidentifiable *Ps*. *ferox* or *horrida*) collected from Monday Night CO_2 traps (low, high, and any outside District), 2005-2023.

Anopheles quadrimaculatus are now considered common in the District. A marked increase in numbers was first detected in 2006 and populations have been detected at higher levels since then (Fig. 1.18). A record number of 9,750 specimens were collected in 2023. This is over a 165% increase from 2022.

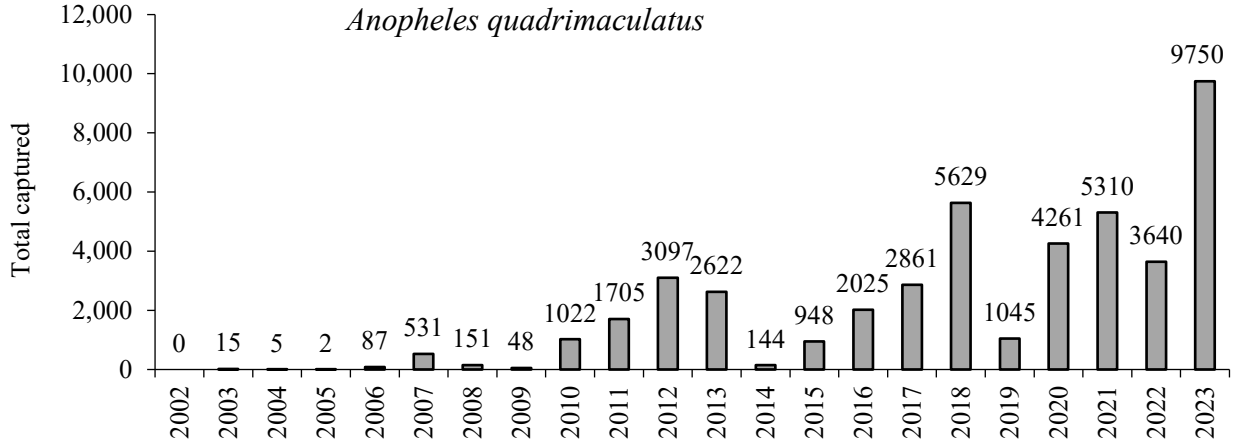


Figure 1.18 Total yearly *An. quadrimaculatus* collected from Monday Night CO_2 traps (low, high, and any outside District), 2002-2023.

Another species that was considered very rare but is now considered uncommon, is *Ae. dorsalis*. It was surprisingly abundant in 2023 (Fig. 1.19) Very high numbers also occurred in 2005, 2010, and 2018 (Fig. 1.19). In 2005, the spring and early summer was wet, and dry conditions took over in July and August. In 2010, the spring was dry and warm; there was no snow in March. In 2018, heavy snows occurred on April 12 (9 inches) and April 14 (16 inches). In all three years, the average season rainfall was 22.82, 24.55, and 22.54 inches, respectively. The spring of 2023 was wet due to the heavy snowpack and spring rains. After mid-May there was little precipitation. In fact, the average rainfall was 14.71 inches. It is unclear what may have led to their resurgence this year; perhaps it is simply a natural fluctuation in their local population. *Aedes dorsalis* is salt tolerant and may travel 22 miles or more from its larval habitat. This species is very common in the western plains of the United States.

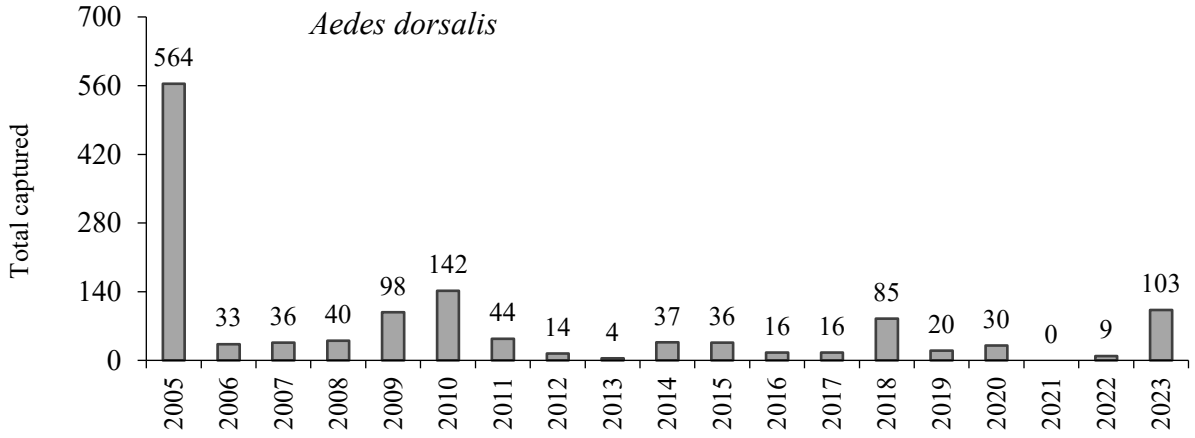


Figure 1.19 Total yearly *Ae. dorsalis* collected from Monday Night CO_2 traps (low, high, and any outside District), 2005-2023.

2024 Plans – Surveillance

Ongoing: Surveillance will continue as in past years. We will evaluate sweep net, CO_2, and gravid trap locations to ensure adequate distribution and that target species are collected.

CO_2 trap comparison: In 2023, we began a study to compare our current CO_2 trap style (American Biophysics ABC trap) with a new type of CO_2 trap (Biogents BG-Pro) The new trap is different than the current style. Most notably, it uses LED rather than incandescent light; the airflow is bidirectional where the ventilator creates a downward flow though the suction funnel in the center of the trap then the airflow changes direction inside the trap body and is released through the top surface surrounding the suction funnel; and the collection bag is placed above the fan which reduces specimen damage. The study is designed to compare the two types of traps to determine if there is a difference in the species composition and abundance, as well as the amount of nontarget insect bycatch captured.

We began the study on June 21, 2023. We had four study locations and ran the two trap types (we eliminated the BG Pro with light which collected excessive bycatch) at each location for two consecutive nights, swapping the trap location on the second night. Unfortunately, lack of floodwater and cattail mosquitoes, and trap failures resulted in collecting minimal data. We intend to continue this study in 2024.

Long-term CO_2 Trap analysis: We now have three years of data so we will evaluate species richness between trap locations, regions, and even against New Jersey trap results.

Faunal paper: In 2023, we reevaluated our species abundance rankings (Appendix A) and will continue the goal to publish a checklist of the mosquito fauna of the Twin Cities metropolitan area.

Chapter 2 Mosquito-borne Disease

2023 Highlights

- There were 43 WNV cases reported in Minnesota residents, 19 in District residents
- MMCD documented a new record WNV infection rate in mosquitoes tested for the virus in 2023
- There was one LAC case reported in the District
- There were two JCV cases reported in the District
- Eastern equine encephalitis was not detected in Minnesota
- WNV was detected in 129 District mosquito samples
- MMCD collected and recycled 11,139 tires

2024 Plans

- Provide surveillance and control for La Crosse encephalitis prevention
- Work with others to better understand Jamestown Canyon virus transmission
- Conduct catch basin and stormwater structure larvicide treatments to manage WNV vectors
- Communicate disease prevention strategies to other local governments
- Conduct surveillance for WNV and other mosquito-borne viruses
- Monitor for *Ae. albopictus* and other invasive species
- Conduct *Cs. melanura* surveillance and control 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 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 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.

2023 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 2023, District staff recycled 11,139 tires that were collected from the field (Table 2.1). Since 1988, the District has recycled 734,208 tires. In addition, MMCD eliminated 2,331 containers and filled 96 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 10 seasons and long-term averages

Year	Tires	Containers	Tree holes	Total
2014	21,109	3,297	478	24,884
2015	24,127	2,595	268	26,990
2016	18,417	1,690	261	20,368
2017	14,304	1,809	298	16,411
2018	9,730	1,993	478	12,201
2019	9,763	1,611	395	11,769
2020	11,824	3,134	375	15,333
2021	10,939	1,086	162	12,187
2022	11,753	1,087	92	12,392
2023	11,139	2,331	96	13,566
Ave 2000-2023	16,460	2,671	596	19,727

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 2023, there were 28 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 2023, MMCD staff collected 1,700 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 140 aspirator samples. Adulticides were applied to wooded areas in 22 of those cases. Adult *Ae. triseriatus* were captured in 281 of 1,440 wooded areas sampled. The mean *Ae. triseriatus* capture was the third lowest observed over the past 20 years (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
2004	1,850	786	42.5	3,101	1.34
2005	1,993	700	35.1	2,617	0.84
2006	1,849	518	28.0	2,680	0.78
2007	1,767	402	22.8	2,345	0.42
2008	1,685	495	29.4	2,429	0.64
2009	2,258	532	24.0	3,125	0.56
2010	1,698	570	33.6	2,213	0.89
2011	1,769	566	32.0	2,563	0.83
2012	2,381	911	38.3	3,175	1.10
2013	2,359	928	39.3	2,905	1.22
2014	2,131	953	44.7	2,543	1.45
2015	1,272	403	31.7	1,631	0.72
2016	1,268	393	31.0	1,590	0.75
2017	1,173	361	30.8	1,334	0.98
2018	1,211	374	30.9	1,394	0.75
2019	1,055	342	32.4	1,170	0.97
2020	1,604	437	27.2	2,001	0.57
2021	1,516	309	20.4	1,959	0.42
2022	1,258	245	19.5	1,459	0.57
2023	1,440	281	19.5	1,700	0.48

Aspirator sampling began during the week of May 23 and continued through the week of September 4. Weekly mean collections of *Ae. triseriatus* remained well below the long-term average most of the season due to drought conditions (Fig. 2.1). We observed a season peak of 1.27 *Ae. triseriatus* per sample during the week of August 14.

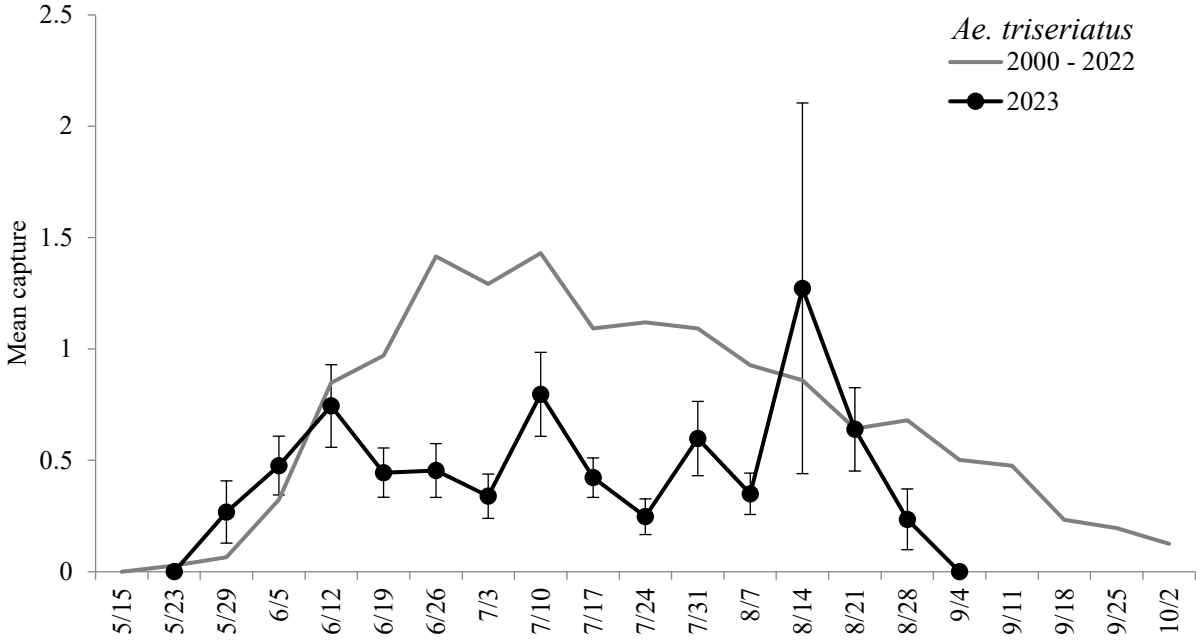


Figure 2.1 Mean number of *Ae. triseriatus* adults in 2023 aspirator samples plotted by week compared to mean captures for the corresponding weeks of 2000-2022. Dates listed are Monday of each week. Error bars equal ± 1 standard error of the mean.

La Crosse Encephalitis in Minnesota There was one LAC case reported in Minnesota in 2023 in a resident of Scott County. Since 1970, the District has had an average of 1.93 LAC cases per year (range 0-10, median 1). Since 1990, the mean is 1.24 cases per year (range 0-8, median 0).

Invasive Species Each season, MMCD conducts surveillance for invasive mosquito species. MMCD laboratory technicians are trained to recognize invasive 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 invasive mosquito 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 United States 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 America and commonly collected throughout the District.

Aedes albopictus *Aedes albopictus* were collected in 16 samples in 2023. All of the samples were collected from a tire recycling facility or adjacent properties in Scott County. Specimens were reared from 10 ovitrap samples collected over four weeks from September 1 to September 22. Five gravid trap samples contained the species; specimens were collected on June 14, June 22, August 2, August 23, and August 30. One BG Sentinel sample contained *Ae. albopictus* on August 30. Routine surveillance of tires and containers from throughout the District did not result in the collection of *Ae. albopictus* larvae in 2023.

This was the 21st year in total and 12th consecutive year when *Ae. albopictus* were collected by MMCD staff; the first was in 1991. *Aedes albopictus* have been found in four Minnesota counties: Carver, Dakota, Scott, and Wright. The species has not successfully overwintered at any of the Minnesota locations where previously discovered.

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

In 2023, *Ae. japonicus* larvae were found in 339 samples. Most were from containers (123), and tires (80). Larvae were also found in samples from 75 stormwater structures/artificial ponds, 41 catch basins, 19 wetlands, and one tree hole.

The frequency of *Ae. japonicus* occurrence in larval samples from containers and tires generally increased each year as they spread throughout the District. Since becoming more common, the frequency of occurrence has fluctuated. In 2023, we observed a small increase in *Ae. japonicus* collections over the previous two years (Fig. 2.2). Persistent drought has likely resulted in lower collections of the species over the past three seasons. Since arriving in the District, *Aedes japonicus* have been collected less frequently from tree holes than in tires and containers. Of 17 larval samples from tree holes, only one contained the species in 2023.

Aedes japonicus adults were identified in 383 samples. They were found in 159 aspirator samples, 116 gravid trap samples, 71 CO_2 trap samples, 16 two-minute sweep samples, 13 BG Sentinel trap samples, and eight New Jersey trap samples.

In 2023, the rate of capture of *Ae. japonicus* in aspirator samples remained near average for the year with the exception of the season peak during the week of August 14 at 4.4 *Ae. japonicus* per sample (Fig. 2.3). Results for the week of August 14 were heavily influenced by one sample with 43 *Ae. japonicus* out of only 11 samples collected. The District averaged 100 aspirator samples per week for the season.

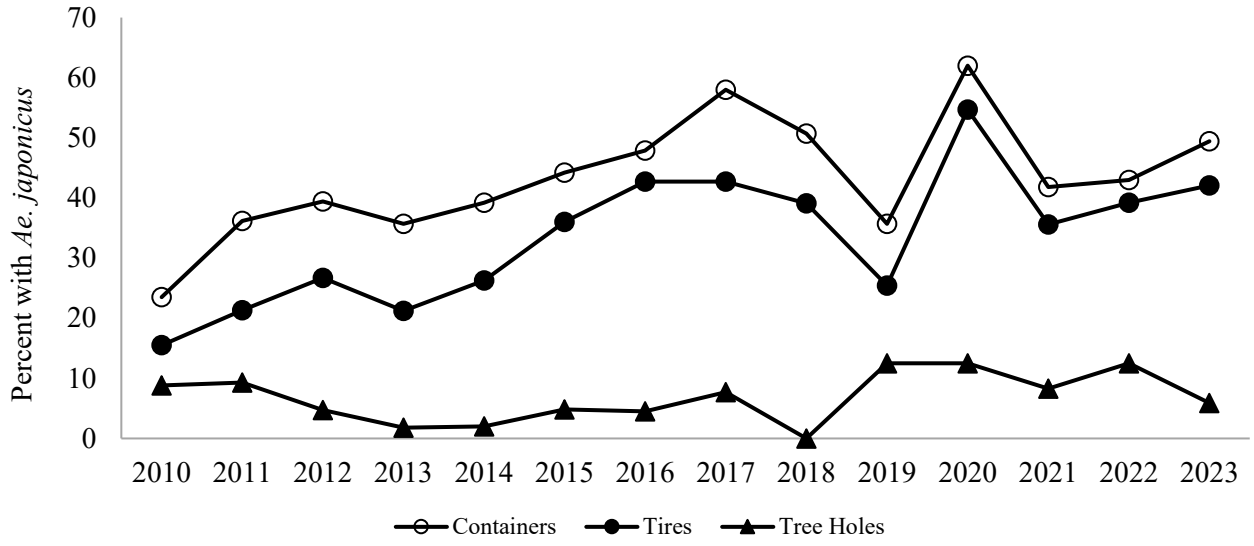


Figure 2.2 Percentage of larval samples from containers, tires, and tree holes containing *Ae. japonicus* by year.

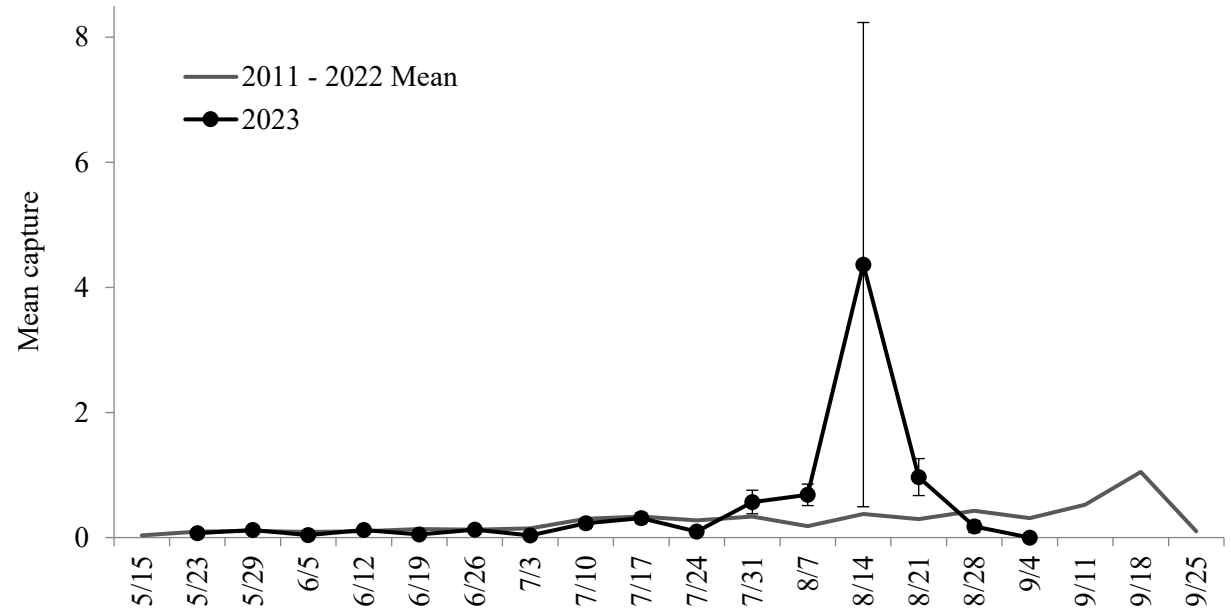


Figure 2.3 Mean number of *Ae. japonicus* adults in 2023 aspirator samples plotted by week compared to mean captures for the corresponding weeks of 2011-2022. Dates listed are Monday of each week. Error bars equal ± 1 standard error of the mean.

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 The U.S. Centers for Disease Control and Prevention received reports of 2,328 West Nile illnesses from 46 states and the District of Columbia. Colorado reported the greatest number of cases with 615. Nationwide screening of blood donors detected WNV in 503 individuals from 46 states and the District of Columbia.

WNV in Minnesota The Minnesota Department of Health confirmed 43 WNV illnesses in residents of Minnesota in 2023. There were 48 reports of WNV positive blood donors from Minnesota residents. Additionally, there were seven veterinary reports of WNV illness in animals in Minnesota.

WNV in the District There were 19 WNV illnesses reported in residents of the District in 2023. There were ten illnesses in residents of Hennepin County, three each in residents of Anoka and Scott counties, two in residents of Dakota County, and one in a resident of Washington County. Since WNV arrived in Minnesota, the District has experienced an average of 10.2 WNV illnesses each year (range 0-27, median 8). When cases with suspected exposure locations outside of the District are excluded, the mean is 8.5 cases per year (range 0-27, median 7).

Surveillance for WNV: Mosquitoes Surveillance for WNV in mosquitoes began during the week of May 23 and continued through the week of September 25. Several mosquito species from 48 CO_2 traps (11 elevated into the tree canopy) and 38 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 818 mosquito pools using the rapid analyte measurement platform (RAMP®), 129 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, 2023; MIR is calculated by dividing the number of positive pools by the number of mosquitoes tested

Species	Number of mosquitoes	Number of pools	WNV+ pools	MIR per 1,000
Cx. erraticus	16	3	0	0.00
Cx. pipiens	1,856	68	11	5.93
Cx. restuans	1,214	44	7	5.77
Cx. tarsalis	308	51	5	16.23
Cx. pipiens/Cx. restuans	7,576	400	66	8.71
Culex species	6,371	252	40	6.28
Total	17,341	818	129	7.44

The hot dry conditions of a third consecutive summer of drought were nearly ideal for amplification of WNV in 2023. The virus was first detected in mosquitoes during the week of May 29 when a mixed *Culex* pool was positive. Only five pools of the primary vector of WNV in human infections, *Cx. tarsalis*, were positive for WNV. However, there were few *Cx. tarsalis* collected during the season, therefore, the WNV infection rate for the species was high. Of the season's 129 WNV positive mosquito samples, 55 were collected in Ramsey Co., 31 in Hennepin Co., 20 in Anoka Co., ten in Dakota Co., seven in Washington Co., four in Scott Co., and one each in Carver and Le Sueur counties.

West Nile virus was detected in mosquitoes collected by MMCD in all but the first, third, fourth and final weeks of testing. Positive results were obtained in consecutive weeks from the week of June 19 through the week of September 18 (Fig. 2.4). The minimum WNV infection rate in mosquitoes peaked during the week of August 14 at 15.89 per 1,000 mosquitoes tested. For the season, the MIR of 7.44/1,000 mosquitoes tested was the highest on record in the District.

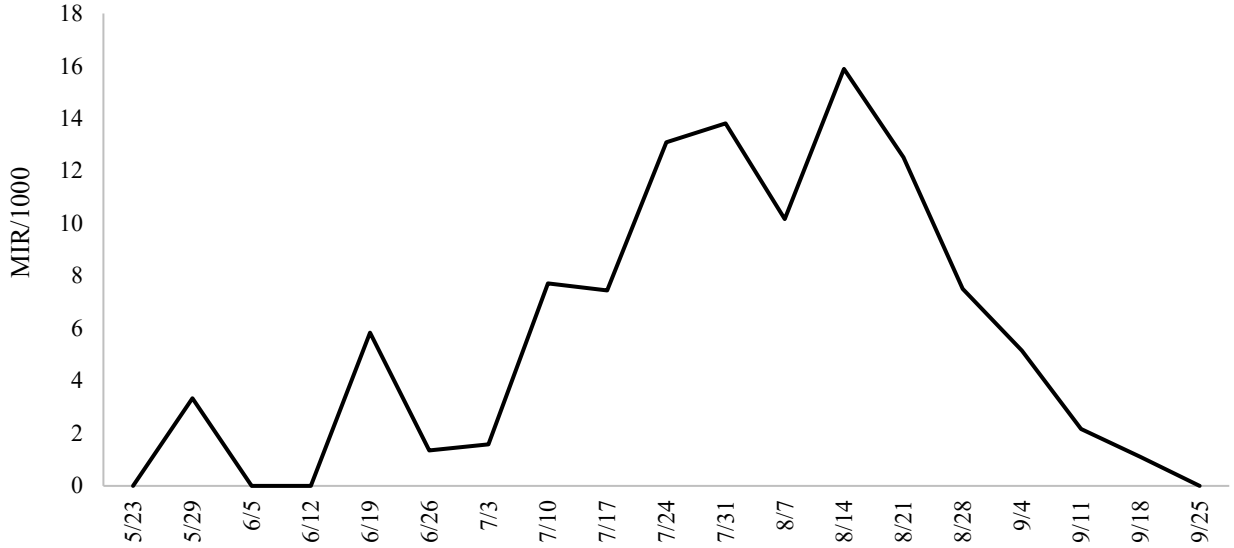


Figure 2.4 Weekly minimum WNV infection rates (MIR) per 1,000 *Culex* specimens tested in 2023. Dates listed are the Monday of the sampling week.

Avian Mortality Since some birds, especially corvids, are susceptible to WNV, the District operates a passive surveillance system to monitor bird mortality. Reports of dead birds aid in identifying areas where WNV might be active. The District received 24 reports of dead birds by telephone, internet, or from employees in the field in 2023. Ten of the birds reported were corvids; eight American crows and two blue jays.

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 2023 season. Weekly mean collections peaked

at 0.97 *Cx. tarsalis* per sample on July 10 (Fig. 2.5). As is typical, few *Cx. tarsalis* were captured by gravid trap in 2023.

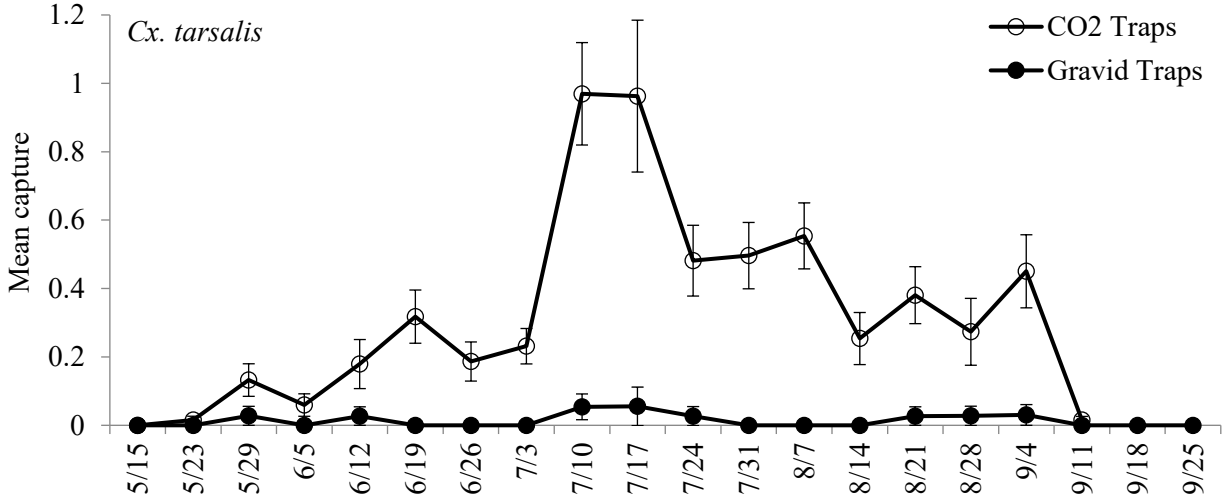


Figure 2.5 Average number of *Cx. tarsalis* in CO_2 traps and gravid traps, 2023. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

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. The CO_2 trap captures of *Cx. restuans* peaked on June 19 at 1.2 per trap. *Culex restuans* were more prevalent than *Cx. pipiens* in gravid traps through the end of June. The peak rate of *Cx. restuans* capture occurred during the week of July 10 at 7.8 per trap (Fig. 2.6).

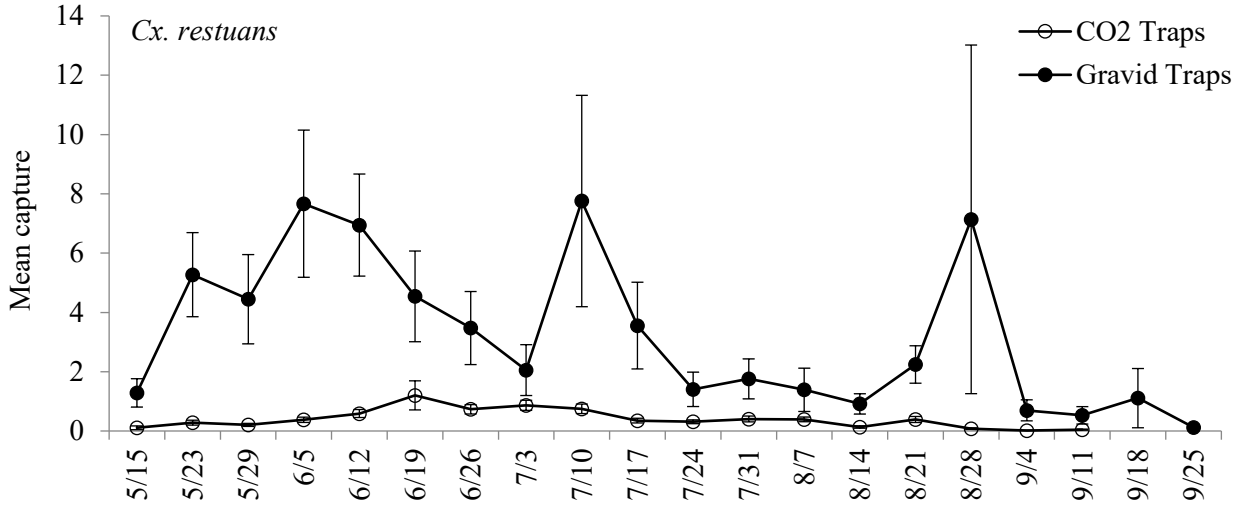


Figure 2.6 Average number of *Cx. restuans* in CO_2 traps and gravid traps, 2023. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

Culex pipiens is an important WNV vector 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 early in the season and peak late in the summer when temperatures are typically warmer. In 2023, the *Cx. pipiens* population was high and collections in both CO_2 traps and gravid traps outpaced collections of *Cx. restuans* early in the summer; from June 26 in CO_2 traps and from July 3 in gravid traps and for the remainder of the season in both traps. *Culex pipiens* collections peaked at 9.9 per gravid trap during the week of July 31 and at 3.6 during the week of August 7 in CO_2 traps (Fig.2.7).

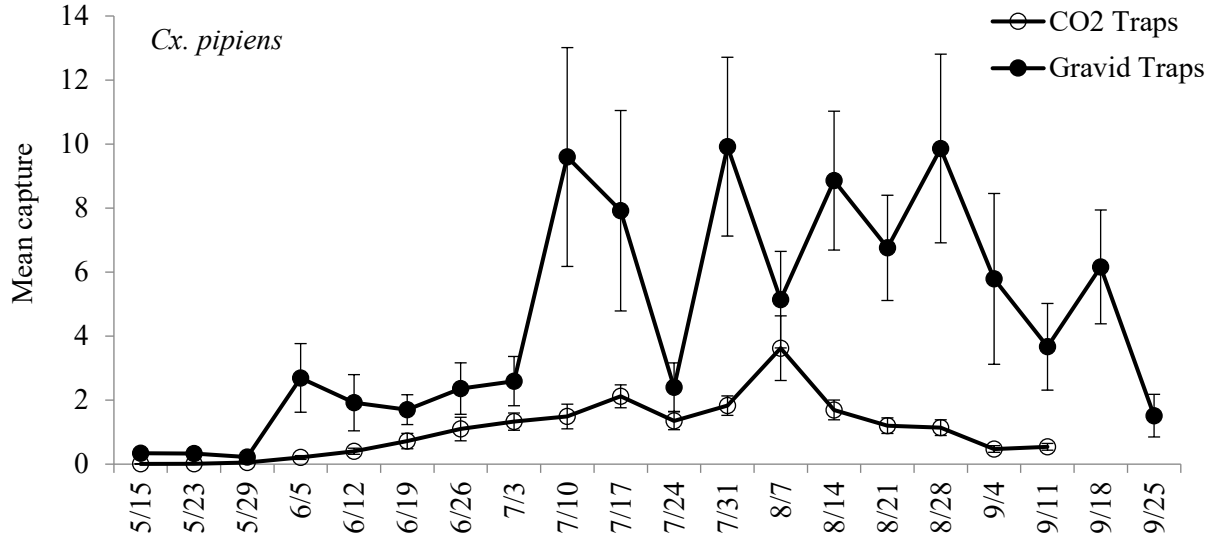


Figure 2.7 Average number of *Cx. pipiens* in CO_2 traps and gravid traps, 2023. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

Often, *Cx. pipiens* and *Cx. restuans* adults are difficult to distinguish from each other. In these instances, they are grouped together and identified as *Cx. pipiens/restuans* (Fig. 2.8). When *Culex* mosquitoes can only be identified to genus level due to poor condition of the specimens, they are grouped as *Culex* species (Fig. 2.9). Both groups usually consist largely of *Cx. restuans* during the early and middle portions of the season with *Cx. pipiens* contributing more to the collections during the middle and later portions of the season. Collections of both groups mimicked each other week to week in 2023 and likely consisted of mostly *Cx. restuans* until early July and mostly *Cx. pipiens* thereafter.

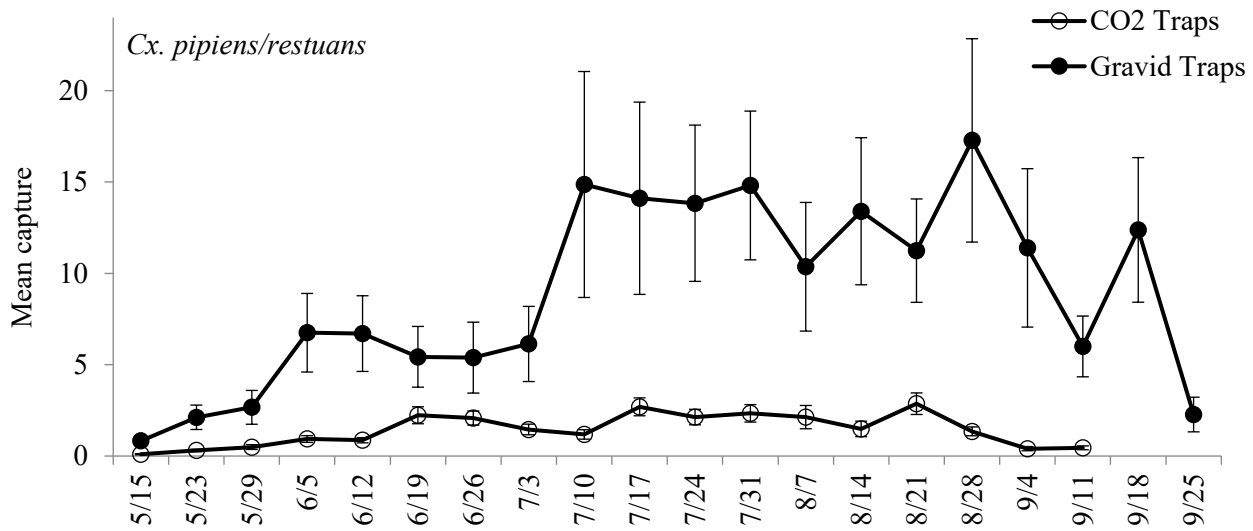


Figure 2.8 Average number of *Cx. pipiens/restuans* in CO_2 traps and gravid traps, 2023. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

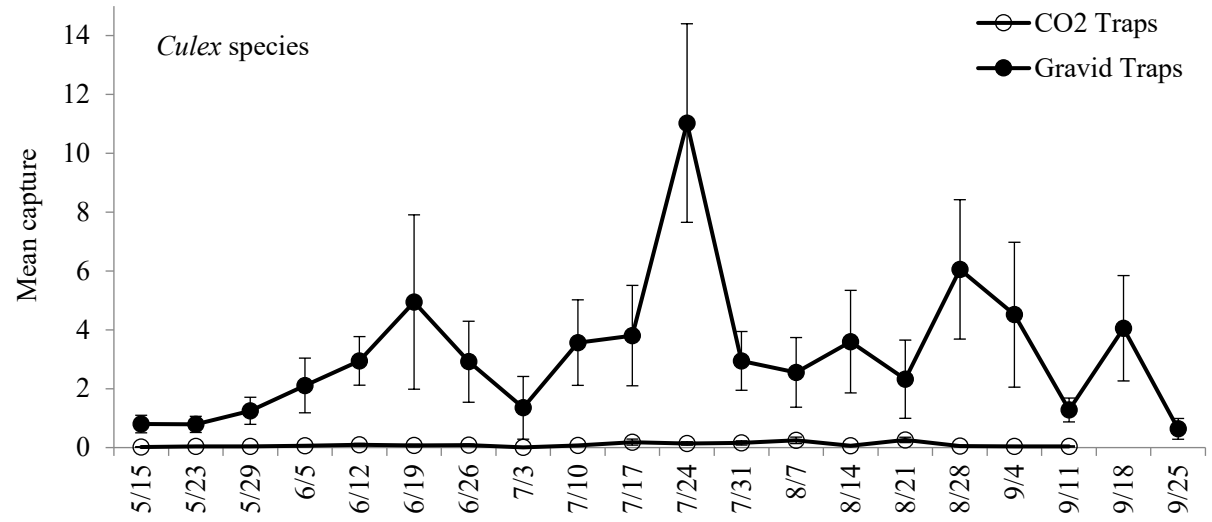


Figure 2.9 Average number of *Culex* species in CO_2 traps and gravid traps, 2023. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

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 habitats, 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.

Technicians collected 1,496 larval samples from stormwater structures and other constructed habitats. *Culex* vectors were found in 89.7% of the samples in 2023 (Table 2.4). *Culex pipiens* were collected at a high rate similar to that of 2022. The frequency of *Cx. restuans* collections was within the range typically observed for these habitats.

Table 2.4 Frequency of *Culex* vector species in samples collected from stormwater management structures and other constructed habitats from 2019-2023

	Yearly percent occurrence				
Species	2019 (N=664)	2020 (N=404)	2021 (N=1,236)	2022 (N=938)	2023 (N=1,496)
Cx. pipiens	5.4	24.0	40.8	65.7	65.2
Cx. restuans	75.0	59.9	65.8	69.1	68.8
Cx. salinarius	0.0	0.0	0.0	0.0	0.1
Cx. tarsalis	3.2	0.7	3.5	2.7	1.3
Any *Culex* vector spp.	79.7	71.0	83.2	89.2	89.7

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 United States Environmental Protection Agency's National Pollution Discharge Elimination System (NPDES). MMCD has worked with city crews to survey and treat underground BMPs since 2005.

In 2023, we continued the cooperative mosquito control plan for underground habitats. Nineteen 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. Municipalities treated 1,020 stormwater structures using 1,286 briquets.

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 assisting with underground stormwater habitat treatments, number of structures treated, and the number of briquets used in 2023

City	No. of structures treated	No. of briquets used	City	No. of structures treated	No. of briquets used
Arden Hills	15	15	Mendota Heights	18	19
Bloomington	92	95	Minneapolis	169	346
Brooklyn Park	4	15	Mounds View	5	5
Columbia Heights	12	16	New Brighton	5	8
Eagan	61	61	Prior Lake	66	66
Eden Prairie	20	20	Roseville	27	29
Edina	61	122	Savage	56	56
Golden Valley	132	132	Shoreview	22	25
Hastings	2	2	Spring Lake Park	3	4
Maplewood	250	250			

Larval Surveillance in Catch Basins Catch basin larval surveillance began the week of May 23 and ended the week of September 18. Larvae were found during 745 of 789 catch basin inspections (94.4%) in 2023. Mosquito larvae were collected in at least 80 percent of catch basins each week of the season and in more than 90 percent of catch basins in 14 of the 18 weeks catch basins were surveyed (Fig. 2.10).

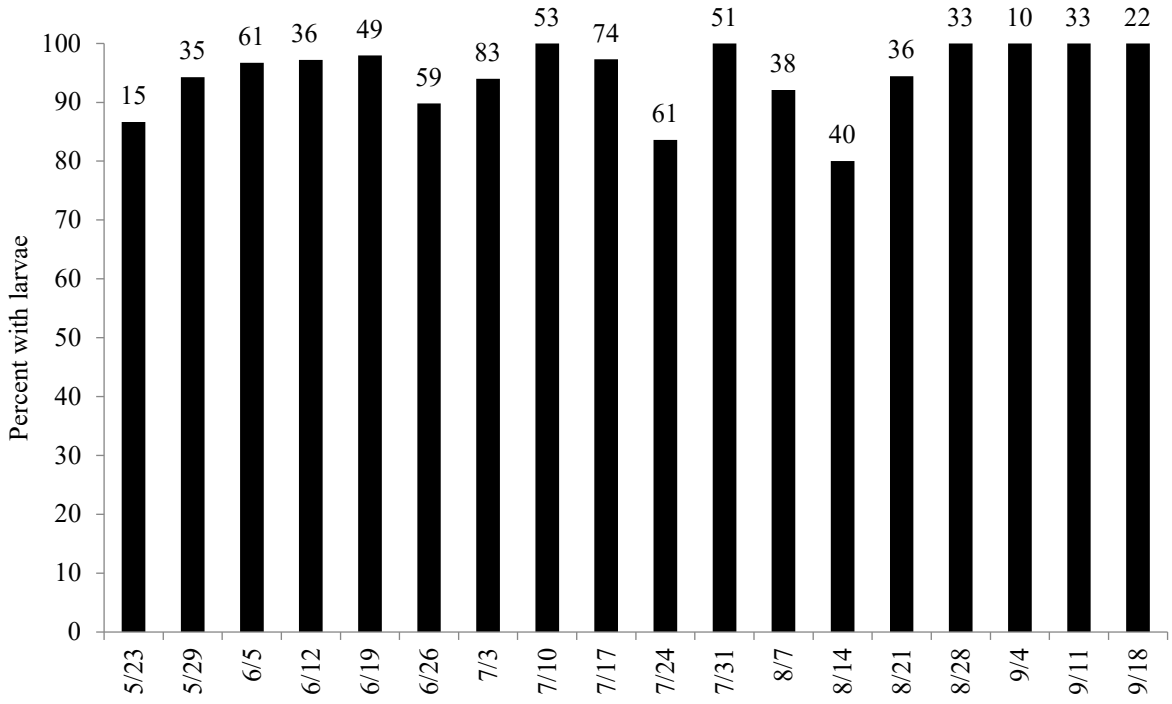


Figure 2.10 Percent of catch basins inspected with mosquitoes present in 2023. Bars are labeled with the number of inspections occurring during the week.

Mosquito larvae were identified from 741 catch basin samples. *Culex restuans* were found in 64.9% of catch basin larval samples. *Culex pipiens* were found in 76.1% of samples. At least one *Culex* vector species was found in 98.5% of samples. *Culex restuans* were collected more

frequently than *Cx. pipiens* until the week of July 3 when *Cx. pipiens* became more prevalent for the remainder of the season (Fig. 2.11).

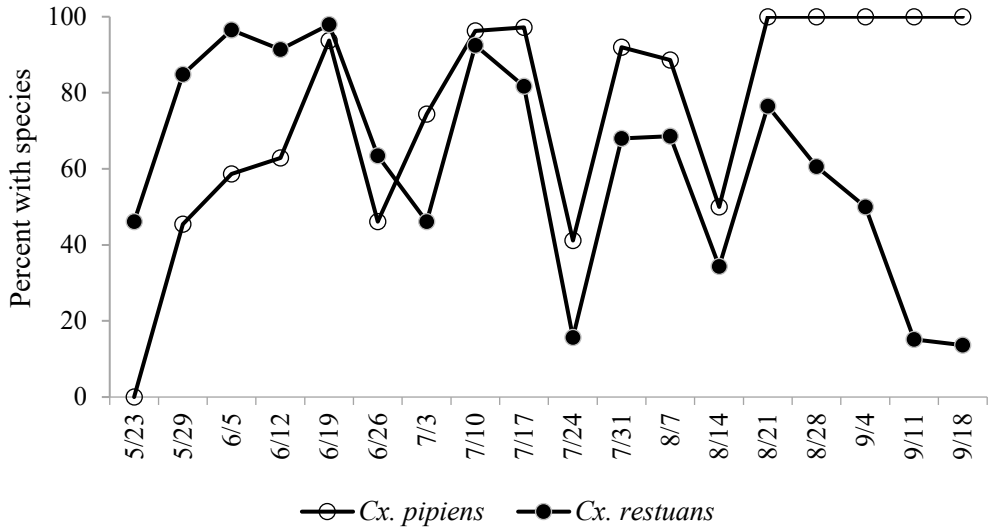


Figure 2.11 Percent occurrence of *Cx. pipiens* and *Cx. restuans* in catch basin larval samples by week.

Eastern Equine Encephalitis (EEE)

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

In 2023, seven human EEE illness were reported to CDC from Alabama, Georgia, Florida, and Louisiana. There were additional reports of EEE activity from 86 counties in 18 states. The nearest EEE detections to Minnesota were in Michigan. There were no detections of the EEE virus in Minnesota in 2023.

***Culiseta melanura* Surveillance** *Culiseta melanura*, the enzootic vector of EEE, is relatively rare in the District and is 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.

Surveillance for adults by CO_2 trap and aspirator indicated the 2023 *Cs. melanura* population was low. So few *Cs. melanura* were collected that no samples were pooled for EEE testing in 2023.

District staff monitored adult *Cs. melanura* at 11 locations (Fig. 1.5, p. 8) using 12 CO_2 traps. Six 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 during the week of May 15 (Fig. 2.12). The population remained low throughout the season with a maximum capture of 0.33 per trap during the week of May 29.

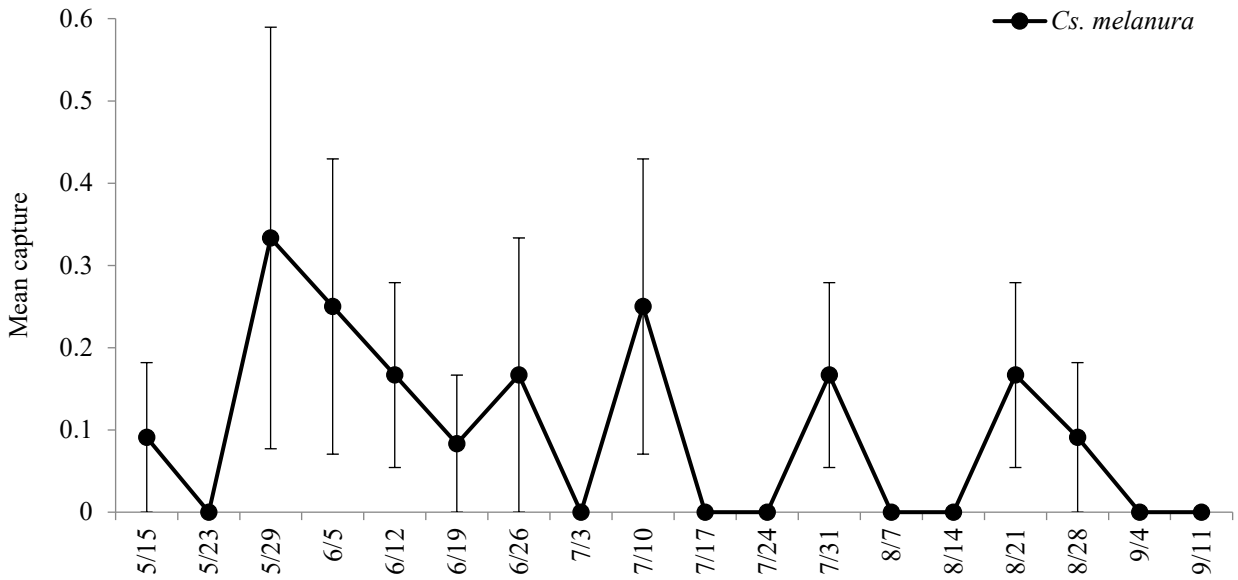


Figure 2.12 Mean number of *Cs. melanura* adults in CO_2 traps from selected sites, 2023. Dates listed are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

Staff collected a season total of only 12 *Cs. melanura* in 67 aspirator samples from wooded areas near bog habitats. The first aspirator captures of *Cs. melanura* occurred during the week of July 17 (Fig. 2.13). *Culiseta melanura* adults were collected during just two of the six weeks with aspirator samples. The peak rate of capture was 0.3 *Cs. melanura* per sample during the week of July 24.

Culiseta melanura develop primarily in bog habitats in the District, and larvae can be difficult to locate. In 2023, with water levels low in bog sites, only one site was surveyed for *Cs. melanura* larvae. No *Cs. melanura* larvae were collected.

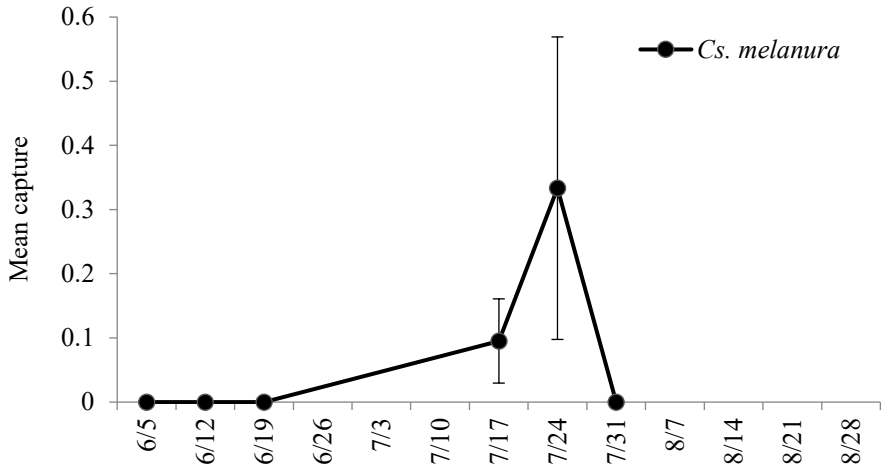


Figure 2.13 Mean number of *Cs. melanura* in 2023 aspirator samples plotted by week. Dates listed are Monday of each week. Error bars equal ± 1 standard error of the mean.

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 by University of Minnesota researchers in southern Minnesota. The virus has not been detected in Minnesota since then. *Culex tarsalis* collections were low in the District in 2023 (Fig. 2.5).

Jamestown Canyon Virus (JCV)

Jamestown Canyon virus is native to North America and circulates among mosquito 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.

Twenty JCV cases were reported nationally from six states in 2023. There were two JCV illnesses reported in Minnesota in residents of Anoka and Ramsey counties.

The District has partnered with the Midwest Center of Excellence for Vector-borne Disease (MCE-VBD) to investigate JCV transmission in the region. Mosquitoes collected by MMCD have been tested at MCE-VBD for JCV. Results from samples collected in 2022 were returned after publication of the 2022 report to the Technical Advisory Board. The virus was not detected in 116 samples tested for JCV.

The MCE-VBD tested adult mosquitoes from the District from 2019-2022. The first three years of the surveillance resulted in positive mosquito samples from *Ae. provocans* and banded-legged spring *Aedes*. Transovarial and transstadial transmission of this pathogen was documented in *Ae. provocans*. After demonstrating that JCV is present in multiple areas of the District, in

multiple species, and in multiple years, the MCE-VBD has decided to no longer spend the resources on further surveillance of JCV in the District.

2024 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

2023 Highlights

- Number of sites positive for *Ixodes scapularis* was 74 out of 100
- Average *I. scapularis* per mammal was 1.03
- *Amblyomma americanum* tracking by the MMCD and/or MDH: 6 adult ticks; 3 female, 3 unknown sex
- Latest available (2022) Lyme case total: 2,685 (source CDC)
- 2021 anaplasmosis: 603 confirmed + probable cases (source MDH)
- Tularemia, Powassan virus, and *I. scapularis* testing; all results pending

2024 Plans

- *I. scapularis* surveillance continues at 100 sampling locations
- Education, identifications, and homeowner consultations
- Update the Tick Risk Meter, provide updates on Facebook, and post signs at dog parks
- Track collections of *Amblyomma americanum* or other new or unusual tick species, including *Haemaphysalis longicornis*
- Participate in the inter-agency collaboration across MN for *H. longicornis* tracking
- Drag for ticks at parks and other nature areas and send to CDC and/or MDH for pathogen testing
- Powassan and SARS-CoV-2 testing

Background

Infected *Ixodes scapularis* (deer/blacklegged tick) transmit the bacterial pathogens of Minnesota's two most prevalent tick-borne diseases: Lyme disease (*Borrelia burgdorferi*), and human anaplasmosis (*Anaplasma phagocytophilum*), and also pathogens that cause rare diseases like human babesiosis and Powassan virus. Attachment time influences transmission.

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 forming the Lyme Disease Tick Advisory Board (LDTAB) to assist with the development of a tick surveillance program. The LDTAB included MMCD and MDH staff, local scientists, and experts from other agencies.

Over the period 1990-1992 the MMCD's tick surveillance program sampled 545 sites and determined the initial range and abundance of *I. scapularis*. Today, we use a subset (100) of those original sites to continue to identify and monitor *I. scapularis* distribution. In addition, our study allows us to rank deer tick activity throughout the season, to watch for entry of non-native tick species, to educate us and others regarding areas of new or higher *I. scapularis* densities, and in some years, to provide samples for tick-borne disease testing. All collected data are summarized in a report and presented to the LDTAB. Also, the MDH and other agencies use the information for risk analyses or other purposes. The MMCD collaborated with the University of Minnesota (UMN) on spirochete and anaplasmosis studies for over eight years.

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

2023 Tick-borne Disease Services

Lyme Disease and Human Anaplasmosis

Movement of *I. scapularis* into Hennepin and Scott counties was first detected in 1998, the first of two years with slightly higher *I. scapularis* collections than in prior years. An obvious increase to higher yearly *I. scapularis* collection numbers followed, in 2000. Yearly collections have maintained that increased level since, with *I. scapularis* expansion following the initial increase in abundance. In parallel, but with a two-year lag (to 2002), the MDH documented higher numbers of human tick-borne disease cases statewide, after a small increase to the case totals had occurred during the two years prior. In 2002 their Lyme disease case totals (confirmed only) had doubled, to 867, from 2000's (463) and 2001's (465) previous record highs. Since 2004, yearly Lyme disease cases have typically averaged >1,000 (range 896-1,431 cases). The all-time Lyme disease record high case total of 2,685 occurred in 2022, however the Centers for Disease Control and Prevention (CDC) revised the case definition for Lyme disease that year which "precludes detailed comparison with historical data." The increase in cases is most likely due to changes in surveillance methods rather than change in disease risk. Human anaplasmosis (HA) cases (confirmed + probable) have also been on the rise. Through 1999, HA case totals averaged roughly 15 per year, then increased during the 2000-2006 period (ranging from 78 to 186). Another increase occurred from 2007-2022 (range 280-788), with the all-time HA record high of 788 occurring in 2011. The MDH reported 603 HA cases (confirmed + probable) in 2021, the latest year of data 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. *Ixodes scapularis* began expanding its range in 1998 and in 2007 we collected at least one *I. scapularis* from each of the seven counties within our service area for the first time. *Ixodes scapularis* is prevalent now in its preferred wooded habitat across our entire service area, both north and south of the Mississippi River. The 2022 and 2023 Lyme Tick Distribution Study reports will be available on our website when complete (https://mmcd.org/publications/).

The 2023 average number of *I. scapularis* collected per mammal is 1.03. In comparison, from 1990-1999 the yearly averages ranged from only 0.09-0.41, and although the yearly averages in six of the years since 2000 ranged between 0.39-0.80, yearly averages in 17 years were all > 1.0 (Table 3.1). The record high of 2.11 was set in 2022. In 2023, as in all years since 2007 aside from 2011, we collected at least one *I. scapularis* from all seven counties in our service area. We tabulated 74 positive sites in 2023, higher than the yearly positive site totals between 2000-2009 (typically in the 50s) and those for 2017-2022 (all in the 60s). The first time the yearly positive site total was 70 or more was in 2010 and 80 or more, in 2015. The record high of 82 positive sites was set in 2016. Maps are included in our yearly Lyme Tick Distribution Study report.

Table 3.1 Yearly totals of the number of mammals trapped and ticks collected (by tick species and life stage), and the average number of *Ixodes scapularis* per mammal, 1990-2023; the number of sites sampled was 250 in 1990, 270 in 1991, 200 in 1992, and 100 from 1993 to present

			Dermacentor variabilis		*Ixodes scapularis*			
Year	No. mammals	Total ticks collected	No. larvae	No. nymphs	No. larvae	No. nymphs	No. other species[b]	Ave. *I. scapularis* / mammal
1990 [a]	3651	9957	8289	994	573	74	27	0.18
1991	5566	8452	6807	1094	441	73	37	0.09
1992	2544	4130	3259	703	114	34	20	0.06
1993	1543	1785	1136	221	388	21	19	0.27
1994	1672	1514	797	163	476	67	11	0.33
1995	1406	1196	650	232	258	48	8	0.22
1996	791	724	466	146	82	20	10	0.13
1997	728	693	506	66	96	22	3	0.16
1998	1246	1389	779	100	439	67	4	0.41
1999	1627	1594	820	128	570	64	12	0.39
2000	1173	2207	1030	228	688	257	4	0.81
2001	897	1957	1054	159	697	44	3	0.83
2002	1236	2185	797	280	922	177	9	0.89
2003	1226	1293	676	139	337	140	1	0.38
2004	1152	1773	653	136	901	75	8	0.85
2005	965	1974	708	120	1054	85	7	1.18
2006	1241	1353	411	140	733	58	11	0.59
2007	849	1700	807	136	566	178	13	0.88
2008	702	1005	485	61	340	112	7	0.64
2009	941	1897	916	170	747	61	3	0.86
2010	1320	1553	330	101	1009	107	6	0.85
2011	756	938	373	97	261	205	2	0.62
2012	1537	2223	547	211	1321	139	5	0.95
2013	596	370	88	42	147	92	1	0.40
2014	1396	2427	580	149	1620	74	4	1.21
2015	1195	2217	390	91	1442	291	3	1.45
2016	1374	3038	576	153	2055	252	2	1.68
2017	1079	1609	243	45	1101	204	6	1.21
2018	765	1439	219	68	1007	139	6	1.50
2019	1121	1164	280	54	645	181	4	0.80
2020	1109	1264	75	61	1072	49	7	1.01
2021	799	767	131	61	439	135	1	0.72
2022	746	2067	386	109	1474	98	0	2.11
2023	1364	2080	478	204	1241	161	3	1.03

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

[b] other species mostly *Ixodes muris.* In 1999, a second adult *I. muris* was collected.

Tick-borne Disease Prevention Services

Identification Services and Outreach The overall scope of tick-borne disease education activities and services included tick identifications of emailed photos or mailed ticks, updating our Tick Risk Meter on our website, and providing tick-borne disease information via telephone and on MMCD's Facebook page.

Posting Signs, Dog Parks Since the 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 Limited distribution of brochures, tick cards, and/or posters occurred.

Additional Updates & Collaborations

***Ixodes scapularis* tick-borne disease testing** Testing *I. scapularis* for *Borrelia burgdorferi sensu stricto, B. mayonii, B. miyamotoi, Anaplasma phagocytophilum* (both the human and the deer variants)*, Babesia microti*, and *Ehrlichia muris eauclairensis* was completed by the Centers for Disease Control and Prevention. Approximately 28 areas were sampled, some more than once, within 25 state, county, and regional parks, the Cedar Creek Ecosystem Science Reserve, and local nature centers. Each location was dragged for 1,000 meters in the early summer of 2023 and 480 nymphal and 310 adult *I. scapularis* were collected. However, only 478 of these 790 *I. scapularis* were sent to the CDC as their agreement placed a limit on the number of *I. scapularis* ($\leq$ 50 ticks of each life stage) to be tested from any single location. In this dragging effort, *I. scapularis* was collected within all seven District counties and presented a general pattern of greater *I. scapularis* densities in the northeastern portion of the District and low densities in Carver, Dakota, and Scott counties. Results of pathogen testing revealed that all pathogens tested for were present within the District except for *B. mayonii* and *Ehrlichia muris eauclairensis*. A number of ticks were co-infected with multiple pathogens that cause human disease including two nymphs that were infected with three separate pathogens (the human strain of *A. phagocytophilum*, *B. burgdorferi*, and *B. microti*). Across the District, 0.7%, 1.8%, 3.9%, and 22.9% of nymphal *I. scapularis* ticks were infected with *B. miyamotoi*, *B. microti*, *A. phagocytophilum* (human variant), and *B. burgdorferi*, respectively.

Tularemia (results pending) The approximately 400 *Dermacentor variabilis* adults collected incidentally in the *I. scapularis* dragging project and the 680 *D. variabilis* immatures collected via tick surveillance were provided to the MDH to be tested for the presence of tularemia, a bacterium that can infect animals as well as people.

Powassan virus (results pending) This rare virus [yearly Minnesota case totals range from 0-11 (median 4)] is transmitted by three species of ticks [*Ixodes marxi* (squirrel tick), *Ixodes cookei* (woodchuck tick), and *I. scapularis* (deer/blacklegged tick)]. Although *I. cookei* may bite a human on rare occasions (or *I. marxi* even more rarely), *I. scapularis* is the primary human vector due to its propensity to bite humans. For the last several months of the tick surveillance

season staff collected blood samples from mammals obtained via tick surveillance, saved any ticks found on themselves while performing field work, and dragged for ticks. All collections were provided to Dr. Matthew Aliota, University of Minnesota College of Veterinary Medicine for Powassan virus testing.

Asian Longhorned Tick (*Haemaphysalis longicornis)* Surveillance Continued The Asian longhorned tick, first detected in North America on a sheep in New Jersey in the fall of 2017, was later determined to have been present in the United States since at least 2010. The type apparently introduced into the US is parthenogenetic (asexual). The implication is that an introduction of a single tick into an area could potentially cause the Asian longhorned tick to become established in that area. There have been no known introductions of this tick into Minnesota to date.

MMCD continues to participate in an interagency Asian longhorned tick surveillance collaboration. Participating agencies include:

- 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* discovered. Further, the MDH will keep us all informed of the monthly United States Department of Agriculture telemeetings.

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

- Staff will continue to turn in any unusual looking adult ticks for identification
- Our tick identification service that has been in place for many years provides us with a good platform to encourage the public to continue to turn in ticks
- Since *H. longicornis* immatures do not 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
- District-wide tick surveillance by dragging may collect these ticks if they are present in the parks and natural areas we visit
- MMCD staff will distribute the Asian longhorned tick identification cards (with lone star ticks on the opposite side) to help the public learn what to look for and to assist us in detecting any possible introductions
- MMCD will continue to utilize Facebook to keep the public informed of *H. longicornis* updates and to enlist their help in watching for this tick

***Amblyomma americanum* (lone star tick)** *Amblyomma americanum* is an aggressive human biter that can transmit a number of tick-borne diseases. It is also the tick responsible for causing the red meat allergy (alpha-gal syndrome). This tick is more common to the southern U.S., but the range of *A. americanum* is moving northward. *Amblyomma americanum* was first collected by MMCD in 1991 via a road-kill examination of a white-tailed deer (*Odocoileus virginianus*) and specimens have also been submitted to MMCD from the public on a rare, sporadic basis. However, in 2009, for the first time in a number of years, the public submitted *A. americanum* to both MDH and MMCD (from Minneapolis and Circle Pines). From 2009-2023, 55 *A. americanum* were collected by or reported to the MMCD and the MDH. As part of the tick submission process, each agency makes queries regarding travel history, excluding ticks that may have been picked up in places other than Minnesota.

2024 Plans for Tick-borne Disease Services

Surveillance and Disease Prevention Services

The metro-based *I. scapularis* distribution study that began in 1990 is planned to continue unchanged. We will continue our tick-borne disease education activities and services of tick identifications, homeowner consultations, updating the Tick Risk Meter on our website, and using social media. We will stock local government agencies, libraries, and other locations with tick cards, brochures, and/or posters, distribute materials at local fairs and the Minnesota State Fair, set up information booths at events as opportunities arise and offer a comprehensive presentation that covers tick biology, pathogens transmitted that cause disease, 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 typically ceases for the year.

Tick-borne Disease Testing Powassan virus testing will occur from samples collected across the entire 2024 field season. Plans are in progress for collecting additional samples to be used for SARS-CoV-2 testing.

Several local, state, regional, and county parks along with reserves and preserves, nature centers, and wildlife management areas across the District will be dragged for *I. scapularis* ticks and tested for the presence of the same tick-borne pathogens as had been done for the 2023 collected ticks.

Amblyomma americanum and Other New or Unusual Ticks

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

***Haemaphysalis longicornis* (Asian longhorned tick)** We will continue to partner with the other Minnesota agencies involved in the effort to identify possible Minnesota introductions. All agencies will keep each other informed of any Asian longhorned ticks found. An expert in tick identification will independently confirm identification of any suspected Asian longhorned ticks collected by MMCD.

Chapter 4 Mosquito Control

2023 Highlights

- Drought conditions affected larval and adult numbers and treatment acres
- In 2023, 12,851 more acres were treated with larvicide (142,348 acres) than in 2022 (129,497 acres)
- In 2023, 214 more acres of adulticide treatments were made (1,910 acres) than in 2022 (1,696 acres)
- A cumulative total of 317,239 catch basin treatments were made to control WNV vectors
- In 2023, we treated 25,635 more acres for spring *Aedes* (46,056) than in 2022 (20,421)

2024 Plans

- Continue to optimize the available control materials to increase operational efficiency and aid in expansion
- Continue to increase acres treated by UAS with the three facilities that are utilizing a drone in 2024
- Work closely with the Minnesota Pollution Control Agency to fulfill the requirements of a NPDES permit

Background

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

Due to the large size of the metropolitan region (2,975 square miles), larval control was considered the most cost-effective control strategy in 1958 and remains so today. Consequently, larval control is the focus of the control program and the most prolific mosquito habitats (~85,000 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). Some smaller sites (i.e., sites that are smaller than three acres and are difficult to treat by can be treated using a drone (see Chapter 7 for details).

The insect growth regulator methoprene and the soil bacterium *Bacillus thuringiensis* var *israelensis* or *Bti* are the primary larval control materials. These active ingredients are used in the trade-named materials Altosid® and MetaLarv® (methoprene) and VectoBac® (*Bti*). Other materials included in the larval control program are *B. sphaericus* (VectoLex® FG) and *Saccharopolyspora spinosa* or "spinosad" (Natular® G30). Pre-hatch control uses time-release products which can be applied to larval habitat prior to egg hatch for extended larval control. Products have various control durations from 7-150 days dependent on the formulation. In most applications, MMCD uses 30-day products in areas of historical larval production and are targeted to the most prolific sites. The benefits of pre-hatch treatments are longer-term control which allows staff to conduct surveillance and conduct operations in other areas during that timeframe.

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 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 2023: 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 immediately kill mosquitoes and the material dissipates within hours. A description of the control materials is found in Appendix D. Appendix E 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 F and G contain a historical summary of the number of acres treated with each control material. Insecticide labels are located in Appendix H.

The District uses priority zones to focus service in areas where the highest numbers of people 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 less 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. P1 receives 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, 2023.

2023 Mosquito Control

2023 Program Influences

In 2023, our mosquito control program was affected by a few issues. Our goal when facing these issues and others, is to continue to provide as many services as possible to the residents of the District in an efficient and effective manner. The main issues in 2023 and their solutions were:

- **Drought conditions:** Starting in 2021, much of the metro area has been affected by continued drought conditions. With the 2023 snow melt and early precipitation, many of our wetlands rebounded and environmental conditions improved. Breeding sites produced significant spring larval numbers. After this initial wet period, the weather patterns reverted back to drier conditions for the remainder of the year. These conditions impacted the wetlands again which reduced the work employees were conducting in these habitats. Staff focused their work on potential disease reduction. The drought also had a positive effect on our budget, due to the lowered service demands.
- **Hiring seasonal staff:** In 2023, our recruiting efforts improved our ability to hire seasonal staff and most facilities have fulfilled their hiring requirements. In comparison to other local governmental agencies, MMCD's seasonal hiring was above average, and our hiring numbers did not negatively affect our ability to complete our operations. It does seem that seasonal employee working patterns are changing. The overall duration of seasonal staff employment is becoming shorter and many employees prefer time off versus overtime pay. Allowing more employee flexibility in their working time has been well received. Facilities continued to work together to share staff when needed to accomplish the work.
- **Late summer and fall workloads:** As seasonal technicians are leaving employment earlier, this can cause a staff shortage to complete normal mosquito operations and cattail surveillance work. In 2023, MMCD conducted late summer pre-hatch treatments to ensure highly productive mosquito breeding sites were covered in the event of a large rain. This strategy allowed staff to then focus on completing cattail surveillance and allowed MMCD to complete fall VectoLex® FG treatments to cattail sites before the cold weather restricted operations.

Program Results After May 2023, the dry weather pattern continued and our region did not have significant mosquito floodwater production throughout the summer. Adult mosquito abundance was very low overall. Larval and adult control continued to be low when compared with the previous five years (Table 4.1). Hiring additional seasonal staff aided in extending services to additional areas.

Table 4.1 Number of acres treated and number of seasonal technicians hired, 2018-2023

	2018	2019	2020	2021	2022	2023
Acres larval control	187,727	212,172	194,911	150,299	129,497	142,348
Acres adult control	38,479	22,325	6,450	2,573	1,696	1,910
Seasonal technicians	229	229	184	187	179	194

The dry conditions and resultant lower service demands in 2023 continued to keep our expenditures below our 2023 budget. The drought conditions continued to allow our staff to extend our surveillance and control operations. MMCD had the ability to use control materials normally used in P1 areas (currently dry and not producing mosquitoes) in other wet areas to expand the area covered.

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 site treatments and cattail site treatments are based on presence/absence criteria. For treatments by air, larval numbers must meet treatment thresholds. Table 4.2 displays the treatment thresholds established for each species group and priority zone. The threshold is the average number of larvae collected in 10 dips using a standard four-inch diameter dipper. P1 and P2 areas can have different thresholds to help focus limited time and materials on productive sites near human population centers.

Table 4.2 Air site larval thresholds by priority zone and species group in 2023

Priority zone	Spring *Aedes*	Summer *Aedes*	*Culex*4[a]	Summer *Aedes* + *Culex*4 combined
P1	1.0	2.0	2.0	2
P2	1.0	5.0	2.0	2

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

Control for a season begins in the fall of the previous year when we survey cattail sites for larvae of the cattail mosquito, *Cq. perturbans*. Some sites are treated with VectoLex® (*Bacillus sphaericus*) then to eliminate larvae before they overwinter. Some sites where *Cq. perturbans* larvae are limited to holes in cattail mats are treated with Altosid® briquets (methoprene) in February or early March when the wetlands are still frozen. Other sites with cattail mosquito larvae present are treated with controlled release methoprene products (such as MetaLarv® S-PT and Altosid® P35) by air or ground starting in late May to prevent adult emergence (usually peaking around July 4). Surveillance and control for the next season begins again in the fall.

Spring *Aedes* tend to be long-lived, aggressive biters and can lay multiple egg batches. Consequently, they have a lower treatment threshold than summer *Aedes* (Table 4.2), 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 of 2/dip in P1 and 5/dip in P2 is used (Table 4.2). The *Culex*4 (*Cx. restuans*, *Cx. pipiens*, *Cx. salinarius*, *Cx. tarsalis*) threshold is 2 in both priority zones (Table 4.2). If *Aedes* and *Culex* vectors are both present in a site and neither meet the threshold individually, the site can be treated if the combined count meets the 2/dip threshold.

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

Season Overview In 2023, snow melt and heavy rains in April started the season with extensive mosquito larval production (over 43,000 acres). Staff detected the first spring *Aedes* larvae on April 10. Aerial *Bti* treatments to control the spring *Aedes* brood began on April 26, eight days earlier than 2022 (May 5). In 2023, MMCD made the decision to use *Bti* at an 8 lb/acre rate. This change from 2022 re-established the application rate that was used prior to the budgetary reductions. Additionally, staff questioned whether the material at the lower application rate was able to penetrate the dried drought vegetation and reach the water in 2022 spring applications. As spring temperatures started to rise, larvae developed quickly, and staff had significant acreage to evaluate in a limited treatment window. MMCD started helicopter applications at 8 lb/acre, but in an effort to finish the extensive acreage prior to pupation, the District made the decision to temporarily lower the application rate to 5 lb/acre to increase efficiency and acres covered. MMCD completed the scheduled acres on time. Staff continued to expand the larval spring *Aedes* surveillance in P1 and P2 in areas with higher past adult abundance.

The mosquito species composition switched to primarily summer floodwater *Aedes* in early-May; the summer *Aedes* larval threshold was used beginning on May 14. In addition to the spring *Aedes* brood, there were two medium and four small broods of summer floodwater species. There were zero large broods of summer floodwater mosquitoes in 2023 (a typical season has four large broods). A third year of drought conditions led to little need for summer floodwater larval control. Prehatch materials (Altosid® P35, MetaLarv®) were applied in areas that were considered likely to have floodwater egg hatch if water levels rose, but little rain was actually received. Drought also reduced habitat for cattail mosquito larvae, reducing overall control needs for that species (MetaLarv®). A larger proportion of the productive cattail sites were treated in the fall (VectoLex®) which will reduce the need for treatments in May 2024. Figure 4.2 shows the weekly acres treated with the various larvicides used in 2023.

Aerial pre-hatch treatments (Natular® G30, Altosid® P35, MetaLarv® S-PT) to control floodwater *Aedes* were applied in mid-May, mid-June, and mid-August. The late summer application was completed to ensure productive breeding sites were covered as staffing levels dropped. At this time, *Cq. perturbans* surveillance is being completed for September applications and pre-hatch treatments allowed remaining staff to focus on completing that task. This decision paid off as a significant August rain occurred and the pre-hatch minimized the need to pull all staff away from cattail surveillance. Most aerial treatments to control cattail mosquitoes using MetaLarv® S-PT were applied May 21-May 25 (Figure 4.2); VectoLex® FG was applied September 19 to control the overwintering larval cattail mosquito population.

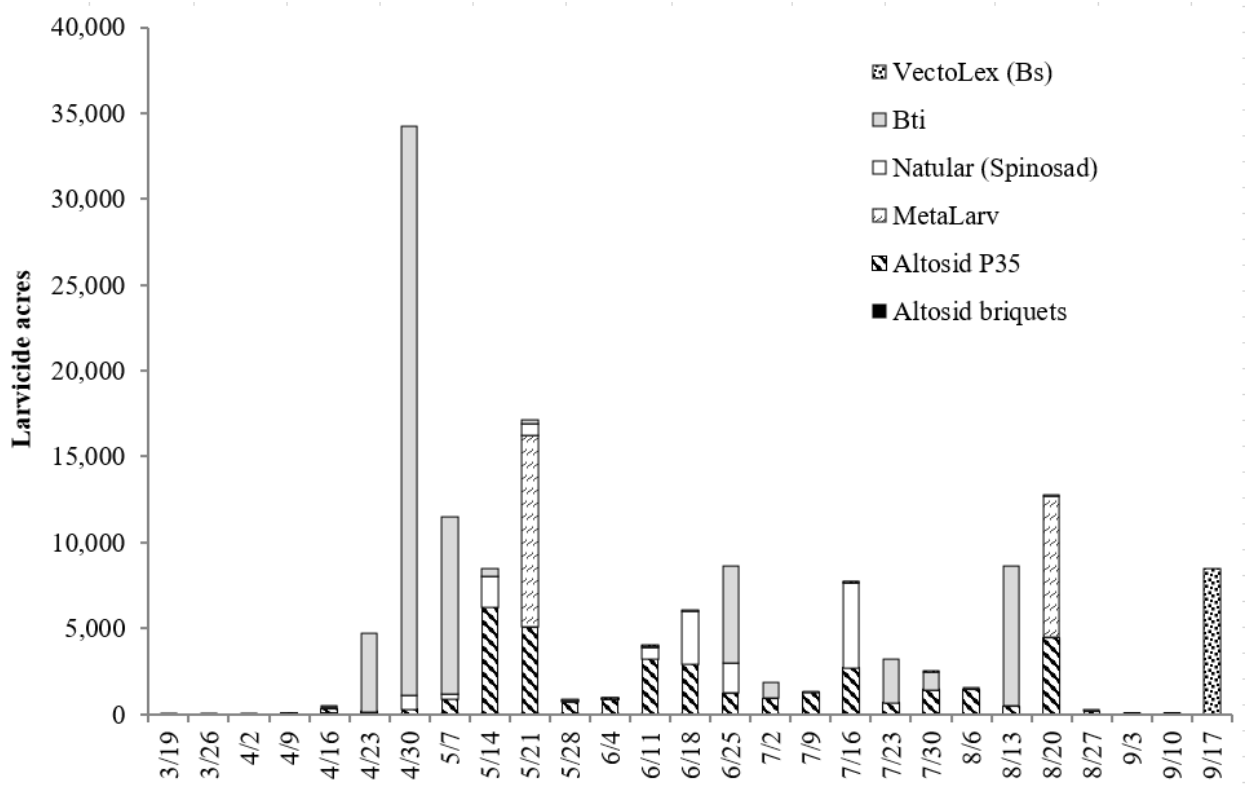


Figure 4.2 Acres treated with larvicide each week (March-September 2023). Date represents start date of week.

The amount of control materials used, and acres treated in 2023 was greater than in 2022 (Table 4.3). The number of acres treated in 2023 was 12.4% greater than the previous year, and the number of catch basin treatments increased by 5.1%.

Spring *Aedes* Control Strategy Larval surveillance for spring *Aedes* was first expanded in 2018 to potentially shift some spring larvicide treatments into P2 to expand the area within the District that received larval control targeting suspected vectors of Jamestown Canyon virus. In 2023, we maintained the P1 spring *Aedes* larval threshold raised in 2018 from 0.5 to 1.0 larva per dip to treat sites that contained higher concentrations of larvae (in both P1 and P2). In 2023, because of our expansion plans to increase spring *Aedes* treatments in P2 and the large increase in suitable habitat for these mosquitoes in P1 due to the remarkable amount of snow that fell over the winter and the early spring rains, we increased treatments substantially from previous years (Table 4.4).

Table 4.3 Comparison of larval control material usage in wetlands, stormwater structures (other than catch basins) and containers, and in stormwater catch basins for 2022 and 2023 (research tests not included)

	2022		2023	
Habitat/Active/Product	Amount used	Acres treated	Amount used	Acres treated
Wetlands and structures				
Methoprene				
Altosid® briquets (cases)	138	119	227	216
Altosid® P35 (lb)	58,543	22,069	96,311	35,357
MetaLarv® S-PT (lb)	56,313	19,296	56,025	19,349
Spinosad				
Natular® G30 (lb)	64,994	13,468	64,712	13,640
CENSOR® G (lb)			5,360	620
B. sphaericus				
VectoLex® FG (lb)	61,951	4,235	120,870	8,537
B. thuringiensis israelensis				
VectoBac® G (lb)	348,838	70,309	366,709	58,067
VectoBac® GS (lb)			46,263	6,549
Methoprene+*Bti*				
Duplex-G			87	13
Total wetland and structures		129,496		142,348
	Amount used	No. CB treatments	Amount used	No. CB treatments
Catch basins				
Methoprene				
Altosid® briquets (cases)	1.48	325	1.48	472
Altosid® P35 (lb)	2,473.58	301,352	2,825.46	316,762
B. sphaericus				
VectoLex® FG (lb)	2.27	136	0.04	5
Total catch basin treatments		301,813		317,239

Table 4.4 Aerial *Bti* treatment-acres to control spring *Aedes* in P1 and P2 during 2019- 2023

	Number of acres treated by year				
Priority area	2019	2020	2021	2022	2023
P1	31,146	18,304	28,008	18,955	42,687
P2	874	0	2,676	1,465	3,369
Total	32,020	18,304	30,684	20,421	46,056

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 4.5). 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 4.5 Threshold levels by sampling method for important nuisance and vector species. *Aedes* spp. and *Cq. perturbans* are considered nuisance mosquitoes; all other species are disease vectors

		Total number of mosquitoes			
Species	Date implemented	2-min sweep	CO_2 trap	Aspirator	2-day gravid trap
Aedes triseriatus	1988			2	
Aedes spp. & *Cq. perturbans*	1994	2 [a]	130		
*Culex*4[b]	2004	1	5	1[c]	5
Ae. japonicus[d]	2022	2	2	2	2
Cs. melanura	2012		5	5	

[a] 2-minute slap count may be used.
[b] *Culex*4 = *Cx. restuans*, *Cx. pipiens*, *Cx. salinarius*, *Cx. tarsalis.*
[c] Aspirator threshold only for *Cx. tarsalis.*
[d] *Ae. japonicus* threshold was changed in 2022; from 2009-2021 it was 1 per collection.

Season Overview In 2023, adult mosquito levels were elevated at the beginning of the season. Spring *Aedes* adult mosquitoes were well above the 23-year average for the entire season and the summer *Aedes* adult mosquitoes were only above the average until early June before dropping to extremely low levels an order of magnitude below the long-term average (Figure 4.3). In 2023, MMCD applied 215 more acres worth of adulticides than in 2022 (Table 4.6, Appendix F). Adult mosquito control was low all season with its greatest peaks at the end of May through mid-June when the adult mosquitoes were most abundant and at the end of August for protecting the millions of state fair-goers from vector species (Figure 4.3). In 2023, we only treated ~2,000 acres as we rely heavily on our larviciding program to keep adult mosquito populations low and mostly reserve adulticiding for public health emergencies related to the detection of mosquito-borne pathogens and human illness.

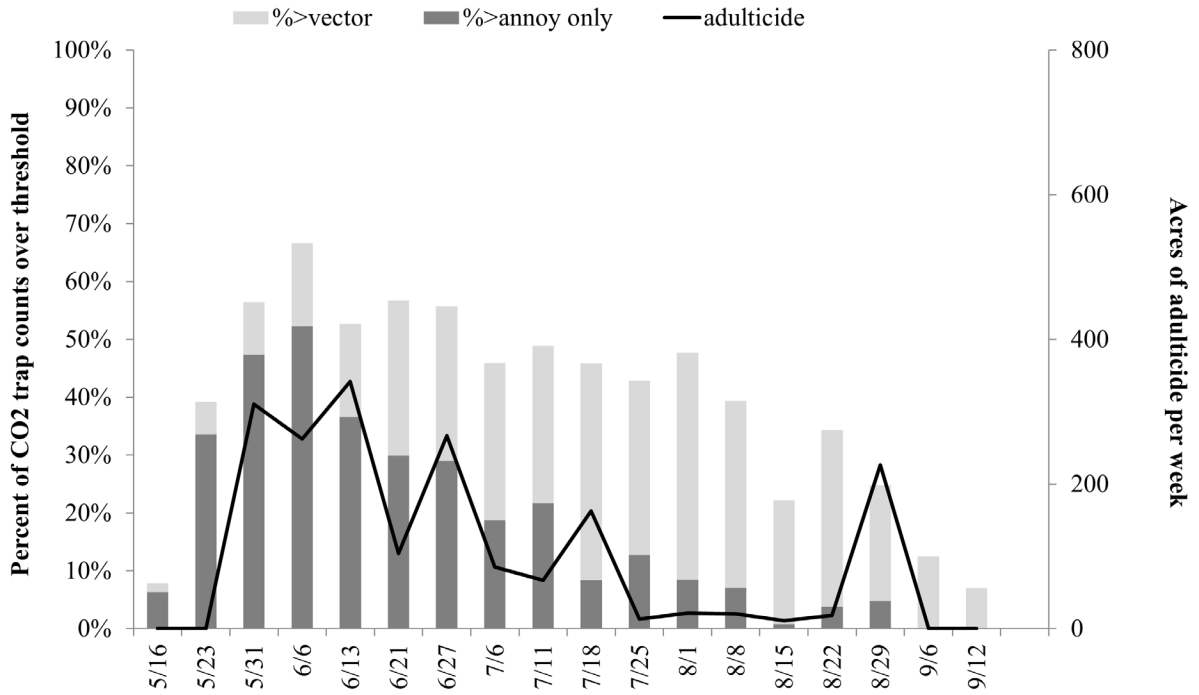


Figure 4.3 Percent of Monday CO_2 trap locations with counts over threshold compared with acres of adulticides applied in 2023 (solid line). Dark bars indicate the percentage of traps meeting annoyance mosquito thresholds and lighter bars represent the percentage of traps meeting the vector thresholds (*Culex*4, *Ae. triseriatus*, *Ae. japonicus*, *Cs. melanura*) on each sampling date. Date is day of CO_2 trap pick up.

Table 4.6 Comparison of adult control material usage in 2022 and 2023

	2022		2023	
Material	Gallons used	Acres treated	Gallons used	Acres treated
Permethrin	65.21	334	139.44	765
Sumithrin*	17.31	722	16.25	756
Etofenprox*	7.44	640	5.33	389
Total	89.96	1,696	161.01	1,911

* 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.

2024 Plans for Mosquito Control Services

Integrated Mosquito Management Program

In 2024, MMCD will continue to review 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, and complying with all NPDES-related permit requirements. Our control materials budget in 2024 will be slightly increased to compensate for inflationary costs of fixed price contracts over the past three years.

Larval Control

Review of Control Material Budget MMCD has historically been conservative in managing its control material budget and often has had significant monies remaining at the end of the year. These funds were often held back for additional rain events that never transpired. Although prudent, we may be able to manage the budget differently to aid us in extending our services. Additionally, we may be able to utilize pre-hatch residual materials to assist with reduced staffing levels in spring or fall timeframes.

Floodwater Mosquitoes The primary control material will again be *Bti* corn cob granules. Larvicide needs in 2024, mainly *Bti* (VectoBac® G), Altosid® P35, Natular® G30, and MetaLarv® S-PT, are expected to be similar to the five-year average larvicide acreage usage (188,888 acres). In 2024, we plan to continue the spring *Aedes* larval threshold used in 2023 (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. Depending on the environmental conditions, we plan to treat spring *Aedes* sites with *Bti* at 8 lb/acre. With each brood, staff will review environmental conditions, budgetary considerations, proposed acreage, and available treatment time to determine if a *Bti* dosage rate change is necessary or pertinent. MMCD may drop to a lower *Bti* application rate when water temperatures are warm and vegetation is low, and this often coincides 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 the amount of control material expensed. Regardless of annoyance levels, MMCD will maintain sufficient resources to protect the public from potential disease risk.

Staff will treat ground sites with Natular® G30, methoprene products (Altosid® P35, Altosid® briquets, MetaLarv® S-PT), or *Bti* (VectoBac® G). 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 2023 (Table 4.2).

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. Drought conditions have impacted site histories and surveillance records of some of our prolific breeding habitats. Some areas may not have produced mosquitoes in 2023, but the mosquito eggs laid in these sites can persist up to 3-7 years. Pre-hatch treatment decisions may be made on surveillance history created over multiple years.

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

Ground and aerial larvicide treatments of wetlands have been increased to control *Culex* species. Catch basin treatments control *Cx. restuans* and *Cx. pipiens* in urban areas. Most catch basins will be treated with Altosid® P35. Catch basins selected for treatment include those found holding water, those that potentially could hold water based on their design, and those for which we have insufficient information to determine whether they will hold water. Treatments could begin as early as the end of May and no later than the third week of June. We tentatively plan to complete a first round of Altosid® P35 treatments by June 25 with subsequent Altosid® P35 treatments every 30 days thereafter.

Cattail Mosquitoes In 2024, control of *Cq. perturbans* will use a strategy similar to that employed in 2023. MMCD will focus control activities on the most productive cattail marshes near human population centers. Altosid® briquet applications will start in February or 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. We will continue to focus efforts where there is potential disease risk, as well as provide service in high-use park and recreation areas and for public functions and respond to areas where high mosquito numbers are affecting citizens.

Additional plans are:

- to use Anvil® (sumithrin) and Zenivex® (etofenprox) as needed to respond to elevated levels of adult mosquitoes as needed
- to use Anvil® and Zenivex® as needed to control WNV vectors including in agricultural areas because current labels now allow applications in these areas
- to ensure all employees who may apply adulticides have passed applicator certification testing for both restricted and non-restricted use products
- review adult mosquito control in regard to potential impacts on endangered species and to protect pollinators

- review available products, equipment, technology, and research to ensure that MMCD is using the appropriate methods in our adulticiding program

Chapter 5 Black Fly Control

2023 Highlights

- Made 88 small stream treatments with *Bti* when the *Simulium venustum* or *S. tuberosum* larval populations met the treatment threshold; a total of 48.9 gallons of *Bti* was used
- Made 33 *Bti* treatments on the large rivers when the larval population of the target species met the treatment threshold; a total of 1,284.4 gallons of *Bti* was used
- Monitored adult populations using overhead net sweeps and CO_2 traps; the average black fly/overhead sweep count was 0.90
- Processed non-target invertebrate monitoring samples from Mississippi River

2024 Plans

- Monitor larval black fly populations in small streams and large rivers and apply *Bti* when treatment thresholds are met
- Monitor adult populations by the overhead net sweep and CO_2 trap methods
- Continue monitoring *Simulium tuberosum* larval and adult populations to understand its distribution and abundance better
- Place non-target study monitoring samplers on Mississippi River

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 by staff at 202 small stream and 31 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 following MMCD's permit from the Minnesota Department of Natural Resources (MNDNR).

The small stream treatment program for *Simulium venustum* began in 1984. *Simulium tuberosum* was included in the small stream treatment program for the first time in 2021 due to the increased population of this human-biting species in recent years. Based on the success of a pilot *S. tuberosum* treatment program in five small streams in 2021, the MNDNR permitted up to two *S. tuberosum Bti* treatments at any of the small stream sites listed on MMCD black fly permit that meet the treatment threshold starting in 2022. A second treatment is allowed for *S. tuberosum*, because there is more than one annual cohort. 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.

2023 Program

Small Stream Program: *Simulium venustum* and *Simulium tuberosum* Control

Simulium venustum and *S. tuberosum* are human-biting black flies that develop in small streams in the MMCD and are targeted for control. *Simulium venustum* has one cohort during the spring and *S. tuberosum* is multivoltine with two or more cohorts. Adults of *S. venustum* and *S. tuberosum* first appear in early to mid-May.

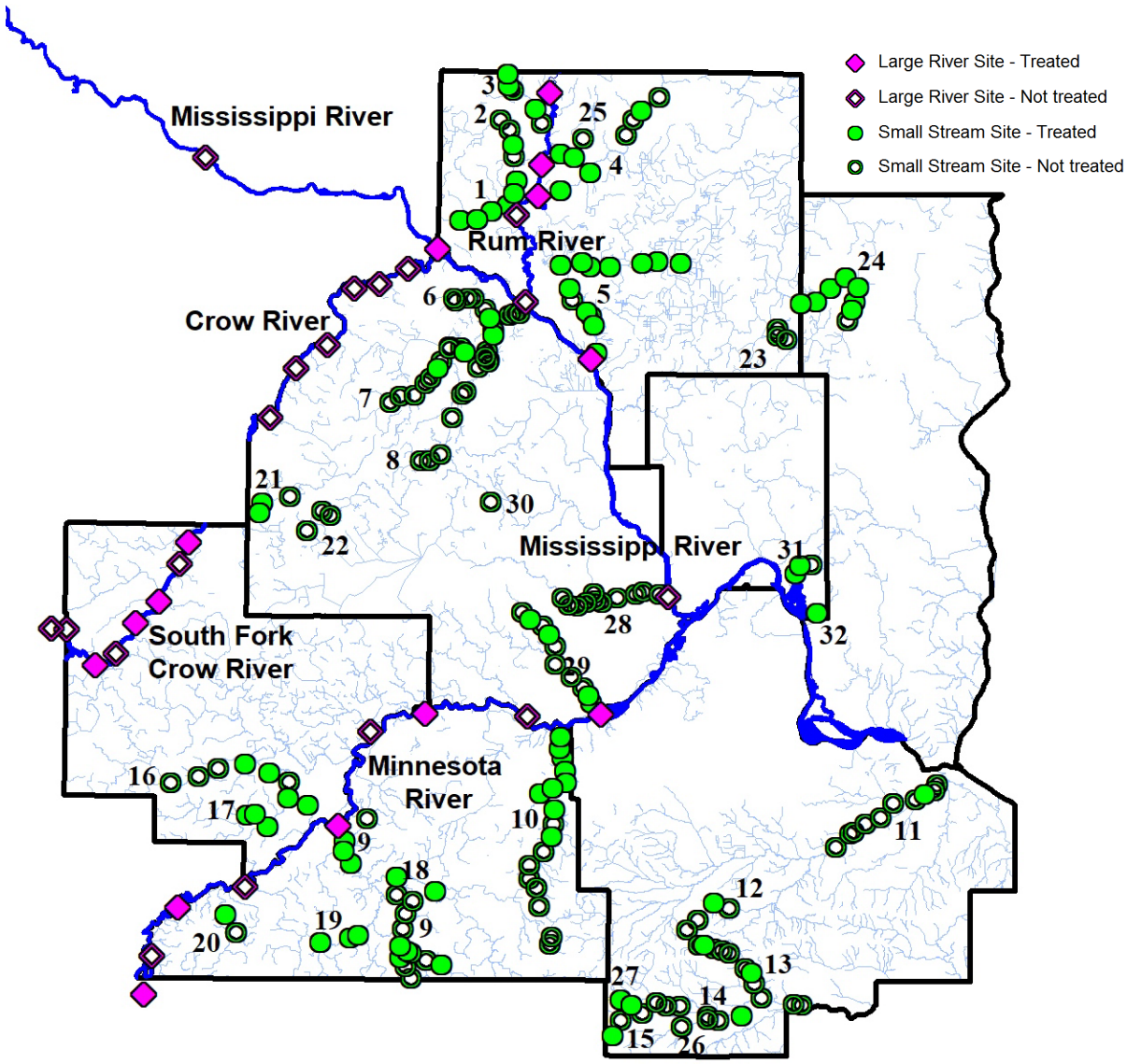


Figure 5.1 Large river and small stream black fly larval monitoring and treatment locations, 2023.

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 and 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* or *S. tuberosum* populations. The numbers on the map refer to the small stream names listed below:

1=Trott	8=Elm	15=Dutch	22=Painter	29=Nine Mile
2=Ford	9=Sand	16=Bevens	23=Clearwater	30=Plymouth
3=Seelye	10=Credit	17=Silver	24=Hardwood	31=Battle
4=Cedar	11=Vermillion	18=Porter	25=Ditch 19	32=Fish
5=Coon	12=Vermillion S. Br.	19=Raven W.Br.	26=Chub Trib. 1	
6=Diamond	13=Chub N. Br.	20=Robert	27=Dutch Trib. 1	
7=Rush	14=Chub	21=Pioneer	28=Minnehaha	

Sampling to assess larval populations of *S. venustum* and *S. tuberosum* for treatment thresholds at the MNDNR-permitted small stream sites was conducted between late April and mid-June using MMCD's standard grab sampling technique. A total of 261 monitoring samples were collected. The treatment threshold was 100 larvae per sample for both species.

In early May, 73 sites on 24 small streams met the treatment threshold for *S. venustum* and these sites were treated once with a total of 44.2 gallons of VectoBac® 12AS *Bti*. The treatment threshold for *S. venustum* was also met twice in May on the Rum River and it was treated with 25.1 gallons of *Bti*. Data for *S. venustum* monitoring and *Bti* treatments on the Rum River are tallied with the large river totals in accordance with the MNDNR permit.

In early May, five sites on two streams met the treatment threshold for *S. tuberosum* and 1.83 gallons of *Bti* were used to treat these sites. A second cohort of *S. tuberosum* was treated at ten sites in mid-June on five streams using 2.84 gallons of *Bti*. One site on the Credit River and two sites on Battle Creek were treated for both *S. tuberosum* cohorts.

A total of 48.9 gallons of *Bti* was applied to the small streams in 2023. In comparison, the average amount of *Bti* used to treat small stream sites annually during 1996-2022 was 28.1 gallons (Table 5.1).

Table 5.1 Summary of *Bti* treatments for black fly control by the MMCD in 2023 versus long-term average

	2023			Long-term average[1]		
Waterbody	No. sites treated	Total no. treatments	Gal. of *Bti* used	No. sites treated	Total no. treatments	Gal. of *Bti* used
Small stream	85	88	48.9	45.2	45.0	28.1
Large river						
Mississippi	2	4	265.1	2.1	10.4	1,131.9
Crow	0	0	0.0	2.0	4.9	90.1
S. Fork Crow	4	5	95.5	5.5	11.6	99.7
Minnesota	5	8	848.3	6.0	16.0	1,741.6
Rum	3	16	75.5	3.3	19.6	143.4
Large river totals	14	33	1,284.4	17.1	58.6	3,173.4

[1] The Mississippi, Crow, Minnesota, Rum, and small stream averages are from 1996-2022. The South Fork Crow average is from 2005-2022.

Large River Program

The MMCD targets larval populations of the large river black fly species that are pests of humans for control with *Bti*. *Simulium luggeri* larvae occur mainly in the Rum and Mississippi rivers, although smaller numbers are also found in the Minnesota, Crow, and South Fork Crow rivers. Depending on river flow, *S. luggeri* larvae are present from mid-May through September. *Simulium meridionale* and *S. johannseni* larvae occur primarily in the Crow, South Fork Crow, and Minnesota rivers. These species are most abundant in May and June, although *S. johannseni* emerge earlier than *S. meridionale*. *Simulium johannseni* are univoltine. *Simulium meridionale*

are multivoltine with the largest numbers occurring in the first cohort in May and June, but populations can also be high throughout the summer if river flows are sufficient for good larval production.

Larval black fly populations were monitored weekly between May and mid-September using artificial substrate samplers (yellow plastic tapes) at the 31 sites permitted by the MNDNR on the Rum, Mississippi, Crow, South Fork Crow, and Minnesota rivers in 2023. The treatment threshold for *S. luggeri* was an average of 100 larvae/sampler at each treatment site location. The treatment threshold for *S. meridionale* and *S. johannseni* was an average of 40 larvae/per sampler at each treatment site location. These are the same treatment thresholds that have been used since 1990.

A total of 336 larval monitoring samples were collected from the large river sites in 2023. The treatment threshold was met in 33 samples from 14 of the permitted sites; the associated sites were treated with a total of 1,284.4 gallons of VectoBac® 12AS *Bti* (Table 5.1). The average amount of *Bti* used annually for the large river treatments between 1996 and 2022 was 3,173.4 gallons. The average number of treatments done annually from 1996 to 2022 was 58.6 at 17.1 sites (Table 5.1).

The average monthly flows between April and September on the Rum, Mississippi, Minnesota, Crow, and South Fork Crow rivers were 28%, 12%, 43%, 51%, and 93% above the long-term average, respectively. Overall, most rivers had above average flows in April and May with levels falling below average by June.

The amount of *Bti* used to treat the large rivers was well below average in 2023 (Table 5.1). Drought conditions throughout Minnesota after May affected the river watersheds during the remainder of the 2023 season. When river flow is reduced because of drought, black fly production declines, resulting in fewer treatments because treatment thresholds are not met. Secondly, since the amount of *Bti* needed to achieve the prescribed dose of 25 ppm for a large river treatment is directly proportional to flow, less *Bti* is required for a treatment if the treatment threshold is reached during drought conditions.

The efficacy of the VectoBac® 12AS *Bti* treatments was measured by determining larval mortality 250 m downstream from the application point 24 hours after most treatments in 2023. Post-treatment mortality was 96% on the Minnesota River, 96% on the Rum River, 100% on the Mississippi River, and 95% on the South Fork Crow River.

Adult Population Sampling

Daytime Sweep Net Collections The adult black fly population was monitored at 54 standard locations (Figure 5.2) using the District's black fly over-head net sweep technique that was established in 1984. Prior to 2004, samples were taken twice weekly. Since then, samples have been 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 2023 was 0.90/sweep (± 6.84 SD). In comparison, the average of all species captured in net sweeps from 1996 (the start of operational *Bti* treatments) to 2022 was 1.21/sweep (± 0.80 SD). 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/sweep (± 3.04 SD) (Table 5.2).

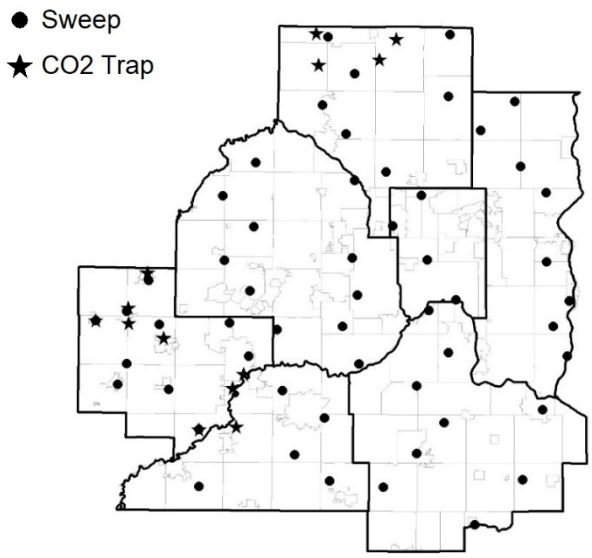


Figure 5.2 Standard overhead sweep net sampling locations (n=54) and CO_2 trap (n=13) sampling locations, 2023.

The county with the highest number of total black flies captured in the sweep net monitoring samples was Hennepin County, where a mean of 2.45 (± 14.5 SD) per sample for all species was recorded. The county with the second-highest sweep net count for total black flies was Scott County, where the mean was 1.18 (± 5.25 SD) per sample. Anoka County was the third-highest county for the net sweep count of total black flies with a mean of 0.75 (± 2.01 SD) per sample.

The most abundant black fly species collected in the overhead sweep net samples in 2023 was *S. luggeri*, comprising 64% of the total black fly adults captured with an average of 0.58 (± 6.57 SD) per sample. The second most abundant black fly species captured was *S. meridionale,* comprising 24.1% of the total with an average of 0.22 (± 1.56 SD) specimens per sample. The third most abundant black fly species captured was *S. venustum,* comprising 10.5% of the total with an average of 0.1 (± 0.91 SD) per sample. Very few *S. tuberosum* were collected in 2023, comprising just 0.11% of the total captured in overhead sweep net samples.

Simulium luggeri was the most numerous in Hennepin County and Anoka County sweep samples. The mean number of *S. luggeri* per sample was 2.32 (± 14.4 SD) in Hennepin County and 0.71 (± 2.01 SD) in Anoka County. *Simulium meridionale* was most abundant in the Scott County samples, with a mean of 0.64 (± 4.46 SD) per sample. Dakota County had the second-highest number of *S. meridionale* with a mean of 0.35 (± 1.15 SD). *Simulium venustum* was most abundant in the Scott County samples, with a mean of 0.50 (± 2.57 SD) per sample.

Table 5.2 Mean number and standard deviation (SD) 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]	Time period	Mean ± SD			
		All species[4]	*Simulium luggeri*	*Simulium johannseni*	*Simulium meridionale*
No treatments	1984-1986	14.80 ± 3.04	13.12 ± 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	1996-2022	1.21 ± 0.80	0.89 ± 0.76	0.01 ± 0.02	0.20 ± 0.27
	2023	0.90 ± 6.84	0.58 ± 6.57	0.000 ± 0.00	0.22 ± 1.56

[1]1988 and 2021 were severe drought years which limited black fly production.

[2]The first year of operational treatments (treatment of any MNDNR-permitted sites) on the large rivers was 1996.

[3]Expanded operational treatments began in 2005 when permits were received from the MNDNR for treatments on the South Fork Crow River.

[4]All species includes *Simulium luggeri*, *S. meridionale*, *S. johannseni*, and all other black fly species collected.

Black Fly-Specific CO_2 Trap Collections Adult black fly populations were monitored from mid-May through June in 2023 with CO_2 traps set twice weekly at nine sites in Scott/Carver counties and four sites in Anoka County (Figure 5.2). These traps augment the daytime sweep net collections in the spring to monitor the *S. venustum* population. The adult black fly populations at these locations have been monitored with CO_2 traps since 2004. Black flies captured in the CO_2 traps were preserved in alcohol.

A total of 118,373 black flies were captured in the CO_2 traps in 2023. The most abundant species collected in 2023 was *S. meridionale,* with a total of 99,348 specimens that comprised 84% of the total black flies collected in the CO_2 samples. *Simulium venustum* was the second most abundant species collected, with a total of 16,512 specimens that comprised 14% of the total collection. The third most numerous species collected was *S. johannseni* with a total of 2,287 specimens that comprised 1.9% of the total. A total of 102 *S. luggeri* were captured in 2023, comprising <0.1% of the total collection. No *S. tuberosum* were collected in the CO_2 trap collections in 2023.

Simulium tuberosum Since 2017, the District started receiving a larger number of complaints from the public concerning biting black flies (locally called gnats). Field investigations of complaints about pestiferous black flies indicated that the species responsible was likely *S. tuberosum.* As it obtained pest level status, *S. tuberosum* was added to the MNDNR permit in 2021 with a treatment threshold. More information on the *S. tuberosum* investigations is available in the 2020, 2021, and 2022 Technical Advisory Board Reports.

Black Fly Annoyance Complaints The number of black fly annoyance complaints in 2023 was 44, compared to 11 in 2021, 151 in 2021, 43 in 2020, 7 in 2019, and 36 in 2018. Most

of the complaints were from Scott County and western Dakota County in the south, and northeastern Hennepin County and north central Anoka County in the north (Fig. 5.3)

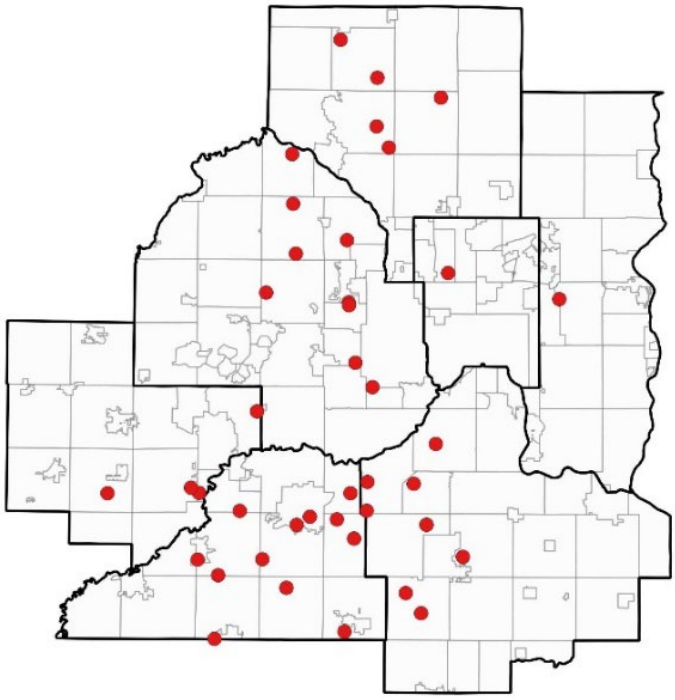


Figure 5.3 Black fly (biting gnats) annoyance complaint locations (n=44), 2023.

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 2023. 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 5.6. The areas in dark gray and black represent the highest numbers collected, ranging from 250 to more than 500 per trap. High to moderate levels of black flies were observed in May through June in parts of Carver, Scott, and Dakota counties (Figure 5.4). The peak average number of black flies occurred on June 5 (Figure 5.5). The average number of black flies was above the 16-year average in May but then below the average for the remainder of the season.

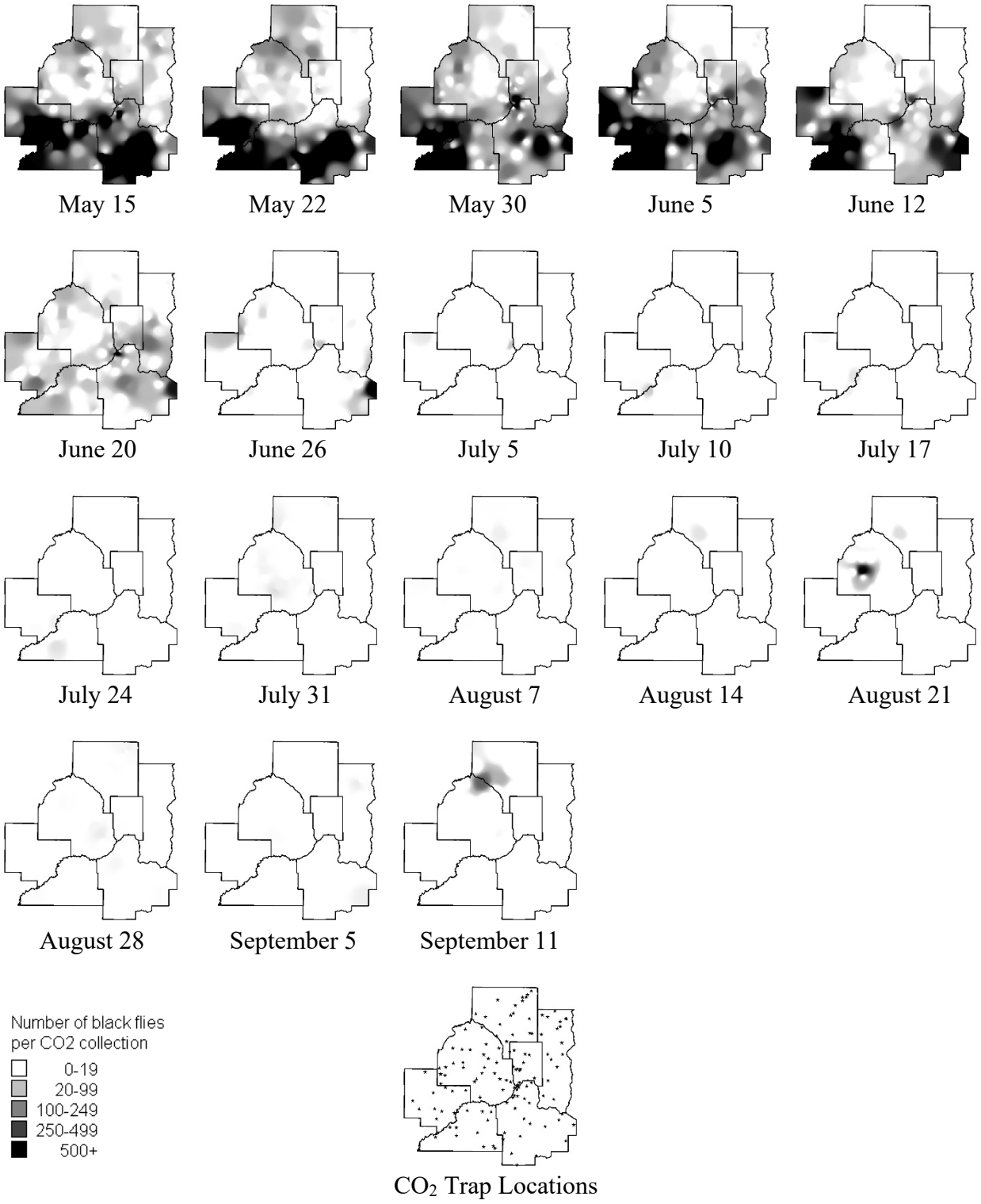


Figure 5.4 Number of black flies collected in mosquito surveillance District low (5 ft) and elevated (~25 ft) CO_2 traps, 2023. The number of traps operated per night varied from 125-133. Inverse distance weighting was the algorithm used for shading maps.

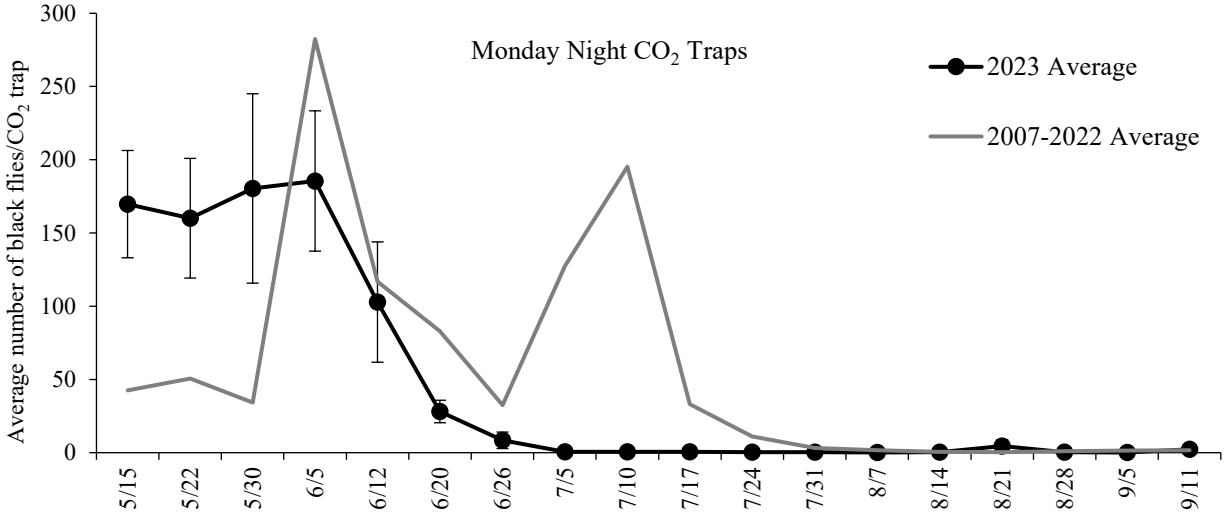


Figure 5.5 Average number of black flies per Monday Night Network CO_2 low trap, 2023-vs. 16-year average (2007-2022).

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 thirteen separate years that monitoring samples were collected biennially between 1995 and 2019 indicate that no large-scale changes have occurred in the macroinvertebrate community in the *Bti*-treated reaches of the Mississippi River.

The drought in the spring and summer of 2021 led to flows in the Mississippi River that were too low for proper deployment of the Hester-Dendy multiplate macroinvertebrate samplers for the scheduled biennial non-target sampling study. The MMCD consulted with the MNDNR about this situation, and it was mutually agreed to delay sampling until 2022. The monitoring samples were collected in 2022. These samples are being processed and a report is scheduled to be submitted to the MNDNR in 2024.

2024 Plans – Black Fly Program

2024 will be the 40th year of black fly control in the District. The primary goal in 2024 will be to continue to effectively monitor and control black flies in the large rivers and small streams. The larval population monitoring program and thresholds for treatment with *Bti* will continue as in previous years. The 2024 black fly control permit application will be submitted to the MNDNR in February. Processing of Hester-Dendy multiplate samples collected in 2022 for the non-target invertebrate monitoring program on the Mississippi River will continue. The Mississippi River non-target monitoring samples will be collected using the 7-plate multiplate samplers as scheduled.

Studies on the distribution, abundance, and ecology of immature and adult *S. tuberosum* will continue to increase the District's understanding of this species. The MMCD will continue to communicate cooperatively with the MNDNR to develop an effective and environmentally sound strategy to reduce the impacts on humans that has been caused by the recent increase in the numbers and range of this species in the Twin Cities area. Program development will continue to emphasize improvements in effectiveness, surveillance, and efficiency.

Chapter 6 Product & Equipment Tests

2023 Highlights

- VectoBac G at the 8 lb rate increased mean mortality by about 10% over the 5 lb rate
- VectoBac® FG *Bti* produced improved control of spring *Aedes* and *Aedes vexans* in air sites
- Evaluations of extended duration products was limited due to continued drought conditions
- Evaluation of LiDAR systems may prove beneficial in habitat topographical mapping

2024 Plans

- Collect more efficacy data to evaluate spring *Aedes* and *Aedes vexans* treatments in air sites
- Continue to evaluate residual products: Natular G30, CENSOR® G and Duplex™-G
- Evaluate expansion of our drone program as it is used in multiple facilities
- Evaluate the Agras T20P & T30 drone platforms
- Continue evaluations of LiDAR, photogrammetry, and geographic mapping in larval habitats using drones

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.

2023 Projects

Quality assurance processes focused on product evaluations, equipment, and waste reduction. Before being used operationally, all products must be evaluated under MMCD field conditions to demonstrate their effectiveness. The District is evaluating six control materials for operational use. 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 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 2023 were all within acceptable limits (Table 6.1).

Table 6.1 AI content of Altosid® (methoprene) briquets and P35 granules; MetaLarv® S-PT granules (methoprene), and Natular® G30 granules (spinosad), 2023

		AI content		
Product evaluated	No. samples analyzed	Label claim	Analysis average	SE
Altosid® XR-briquets	5	2.10%	2.43%	0.0625
Altosid® P35 granules	15	4.25%	4.42%	0.0705
MetaLarv® S-PT granules	15	4.25%	4.17%	0.0307
Natular® G30 granules	15	2.50%	2.30%	0.0245

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 ensure that all adulticides (purchased, formulated, and/or stored) meet the necessary quality standards. Due to no additional adulticide purchases, MMCD did not sample adulticide products or save 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 2023. Aerial *Bti* treatments to control the spring *Aedes* brood began on April 28, eight days earlier than in 2022. The application rate was raised to 8 lb/acre in 2023. This higher rate was the operational treatment rate prior to our reduction to 5 lb/acre rate to conserve budgetary funds. In 2023, aerial *Bti* treatments averaged 79.4% control (Table 6.2), at the 8 lb/acre rate. In April 2023, MMCD did temporarily drop to 5 lb/acre due to time limitations. Larval development was proceeding quickly with warming temperatures and MMCD made the operational decision to cover more breeding acres in the limited treatment window. A lower application rate allows helicopters to fly more acres per load and thus, increase operational efficiency. Percent mortality was calculated by comparing pre- and post-treatment dip counts.

Table 6.2 Efficacy of aerial VectoBac® G applications during the 2023 mosquito season (n = number of sites dipped)

Time period	Dosage rate	n	Mean mortality	±SE*
April 28-May 9	5 lb/acre	106	68.1%	3.7%
April 19-Aug 18	8 lb/acre	273	79.4%	1.9%

*SE= standard error

New Control Material Evaluations

The District, as part of its continuous quality improvement philosophy, strives to continually improve its control methods. Testing in 2023 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.

Larval Control

In 2023, control material research was limited due to the drought conditions and reduced habitat conditions. Therefore, there was a limited focus on product evaluations during the 2023 season.

MetaLarv® S-PT granules In 2022, Valent BioSciences informed MMCD that the current base granule size would be unavailable in the 2023 season. Their vendor will no longer be producing this size granule, and it is not available in the marketplace. Therefore, Valent will be using a smaller granule in their base matrix. MMCD purchased their remaining 2022 product and ran a direct comparison with the new 2023 product. The comparison was to confirm that these were equivalent products.

MetaLarv® S-PT granules and *Coquillettidia perturbans* To evaluate the effectiveness of the new MetaLarv® S-PT granules, we treated five cattail sites with 3 lb/acre on April 13, 2023 or May 31, 2023. We placed five emergence cages into each of the treated sites and in each of five untreated sites. All adult mosquitoes in each emergence cage were collected twice each week beginning on June 13 through July 28, 2023 (at which point many of the test sites were dry). Zero adult *Cq. perturbans* emerged per cage in sites treated with MetaLarv® S-PT granules. During the same period, an average of 3.7 adult *Cq. perturbans* emerged per cage in untreated sites (Figure 6.1). This difference equates to 100% control. Emergence in untreated sites peaked in mid-June which is earlier than normal.

Adult *Cq. perturbans* emerged from significantly fewer cages ($p<0.0001$) in sites treated with MetaLarv® S-PT than in untreated sites during the entire sampling period (Table 6.3). These results also suggest that MetaLarv® S-PT successfully controlled *Cq. perturbans*.

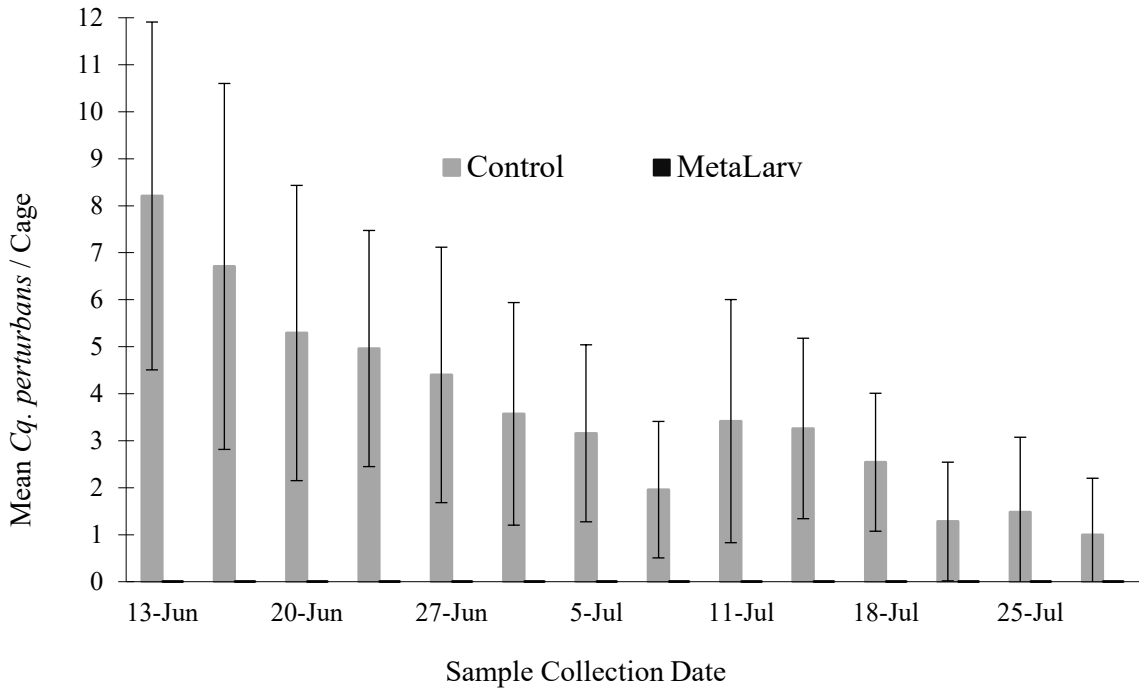


Figure 6.1 Mean emergence of *Cq. perturbans* per sample period in cages in rooted and floating sites treated with MetaLarv® S-PT and untreated (control) sites. Emergence cages were placed on June 11 and sampling occurred from June 13-July 28, 2023. Treatments occurred on April 13 and May 31 (3 lb/acre). Error bars equal ± 1 standard error of the mean.

Table 6.3 Number of emergence cages in untreated sites and sites treated with MetaLarv® S-PT from which adult *Cq. perturbans* emerged during the entire sampling period

Sample Period	Treatment	Total cages	Cages with emergence	Cages without emergence	% Cages with emergence	Fisher Exact P-value
13 June –	Untreated	25	21	4	87.5%	
28 July	MetaLarv® S-PT	25	0	25	0%	<0.0001

Natular® G30 granules MMCD staff requested an updated evaluation of the Natular G30 product to review its efficacy in field operations. An evaluation protocol was developed but dry conditions limited the ability to collect relevant data on the 30-day duration of the product. Further evaluation was postponed until environmental conditions improved.

VectoBac® GS *Bti* granules In the spring of 2022, North Region staff found poor control results in many early VectoBac® G treatments. Technical Services and North staff reviewed multiple application sites and found minimal visual evidence of *Bti* applications. In hypothesizing on possible reasons for poor control, continued drought conditions may have dried down previous year's vegetation to form a shielding barrier that our applications did not effectively penetrate. Our application rate, along with colder water temperatures, may have been too low to achieve adequate control. Larval mosquito activity and feeding rates are reduced in

cold water conditions. In future operations, MMCD may need to increase our flexibility and evaluate more real-time environmental conditions to aid in effectively completing our mission.

To address this issue, MMCD staff desired to look at a different granule size of the VectoBac® product. A smaller granule (GS) (10/14 mesh size) would increase the number of granules per square foot at the same application rate as our current product (5/8 mesh size). MMCD staff also wanted to compare multiple application rates (5 and 8 lb/acre) in these spring sites. Quality spring applications are critical. Many spring mosquito species are long lived, can take multiple bloodmeals, and can contribute to increased risk of vector-borne disease (i.e., Jamestown Canyon virus).

In our North facility, 52 breeding sites were evaluated at the 8 lb/acre rate and achieved 90.54% control. Helicopter applications were completed in ideal low wind conditions and visual observation noted good material coverage of water surface. Two breeding sites were evaluated at the 5 lb/ac rate and achieved 83.50% control. Drought conditions limited additional testing of the lower application rate. When compared to VectoBac®'s 5/8 granule at similar rates, it achieved greater efficacy and staff believed they had better site coverage. MMCD will continue to evaluate this smaller granule in 2024.

Duplex™-G methoprene & *Bti* granules The Duplex™-G granule is a combination product that is designed to provide immediate efficacy and have up to 28 days of residual activity. A dual product may have applicability in situations where multiple broods may occur. The spring season may be a good opportunity to utilize this product. Various spring and summer mosquito species may hatch at different times as site water temperatures warm up. This product would allow staff to visit more sites without returning to the same sites to search for additional broods.

In our North facility, 16 sites were treated at an 8 lb/acre rate and evaluated for immediate and residual control. These sixteen sites demonstrated an average control rate of 65.35% after three days. Eight sites were rechecked and demonstrated an average control rate of 78.07% after six days. The *Bti*'s active ingredients should settle out of the active feeding column and the methoprene component should be the only active control agent after this period. Due to the dry conditions, only two pupal bioassays were able to be completed on the 16 sites to measure emergence inhibition (% EI) of the methoprene component. Within these two independent sites, it showed 97.93% EI at 17 days and 37.96% EI at 20 days, respectively. The initial testing showed that the product may have some applicability in spring sites, but more evaluation of the residual activity is required.

Staff noted that the product was easy to apply but if any field moisture (i.e., dew, rain) hit the stored product, the material had the tendency to clump together. Therefore, making it very difficult to measure or apply the product. Staff did not recommend using this product in ground applications where full bags were not consumed.

CENSOR® G granules The CENSOR® G corn cob granule is a spinosad product with a 7-day residual period. It is designed to work in similar situations where *Bti* granules are currently used in our operations. An advantage of the spinosad active ingredient is that it does not have to

be ingested to obtain control. Therefore, in cold water where mosquito larvae are less active and their feeding activity is reduced, this product may be more effective earlier in the season. It does have some residual activity which may also enhance control when multiple hatches are occurring in the spring.

MMCD evaluated 32 breeding sites. Twenty-six sites produced larvae and treatments achieved an overall average of 65.55% control. Fourteen sites produced over 91% control and six sites showed 0% control. Additional larval hatch seems to have contributed to poor control numbers as dip counts increased in many of those monitored sites. Spring sites, in which efficacy is measured, may have to be visited more often due to varied hatching of different mosquito species.

Adulticide Tests

We did not complete any tests of adulticides in 2023 because of drought conditions that produced low numbers of adult mosquitoes.

Equipment Evaluations

Automated Systems for Insect Identification and Pooling MMCD staff reviewed two automated systems for assistance with taxonomic identification and sample separation. After review, staff determined only one system has the capabilities to meet our sample volume requirements. This developing technology will be monitored to determine if it has applicability, capacity, and ability to assist MMCD in completing our mission.

Senecio Robotics (www.senecio-robotics.com/robotic-surveillance)
The Senecio Robotics automated identification and pooling system is a more advanced piece of imaging and sorting equipment. The device has multiple cameras that image insects moving down a conveyer belt and can sort and pool them with a pneumatic arm. In 2023, Senecio added a new option to their system. A 12-slot carousel was added to allow the system to analyze multiple samples to reduce operator handling and open the possibility to overnight processing.

Technical Services staff conferred with other agencies that purchased the system. Other agencies have worked to increase the number of different species in the system's database. Many of the species added do not reside in the Midwest. Senecio's database still lacks many mosquito species we are interested in for our surveillance and operations. The automated system is relatively slow in processing samples but allowed additional time for taxonomists to work on other responsibilities. This system cannot currently identify adult black flies, ticks, or mosquito larvae. That may be a future option.

The technology is in its early stages of development. A fully operational system that can identify all our species would be considered, but staff could not justify the current benefits, significant expense, or the time and effort required to help develop the vendor's products. MMCD may assist vendors by providing identified specimens to build their species databases. Senecio Robotics is an Israeli company, and the current political situation may hinder company operations and product development.

Helicopter Swath Analysis and Calibration Procedures for Larvicides Technical Services and field staff conducted four aerial calibration sessions for dry, granular materials during the 2023 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 Le Sueur Municipal Airport in Le Sueur, MN and at Benson Airport in White Bear Lake, MN. Staff completed swath characterizations for seven different operational and experimental control materials. In total, six Jet Ranger helicopters were calibrated, and each helicopter was configured to apply an average of five different control materials.

Technical Services and Valent BioSciences technical staff conducted evaluations for two new control materials (Altosid® Duplex™-G granules and Natular® G granules). Field applications and efficacy will be evaluated in 2024.

Drone Swath Analysis and Calibration Procedures for Larvicides Technical Services aided in aerial calibration sessions for various drone models (Agras T-10, Agras T-20, PrecisionVision 22) for dry, granular materials in field sites. Staff completed swath characterizations for three control materials applied in 2023 (Altosid® P35 granules, Valent MetaLarv® S-PT granules and Valent VectoLex® FG granules).

Malvern Laser: ULV Droplet Evaluations Technical Services uses this equipment to evaluate truck-mounted, UTV-mounted, backpack, and handheld ULV generators. In 2023, the District converted its truck-mounted sprayers to all London Fog 18-20 cold foggers. With this conversion, the manufacturer conducted all flow rate calculations and droplet testing as part of the purchase agreement. In 2023, Technical Services did not complete any spray evaluations. Due to the low numbers of adult mosquitoes the past three seasons, the other spray equipment did not exceed the recommended hours of use for droplet characterization, but all product flow rates were verified prior to use.

LiDAR Technology Evaluation MMCD partnered with Frontier Precision to evaluate the capabilities of a drone-mounted LiDAR system. Light Detection and Ranging (LiDAR) systems use a pulsed laser to measure distances to the ground. Through this flight process, the unit can produce a map of earth contours similar to physical surveying. The advantages of such a system are that it can be done efficiently by air without entering the site. Theoretically, it can penetrate vegetation and provide an accurate topographical map to differentiate lower elevations which could hold water. Therefore, LiDAR may help to identify

mosquito habitats which may be obscured by vegetation and assist the direction of staff to effectively find these specific areas. The state periodically conducts low resolution flights which are available to government organizations. Our goals were to complete higher resolution flights to see how these units work to detect water and specifically review how our mosquito habitat is represented in those generated maps. LiDAR mapping has not been used extensively in the mosquito control industry.

Two evaluation areas were chosen in our Maple Grove region. These areas had a wide variety of vegetation types surrounding mosquito habitat. The goal was to see if we could determine water levels in our sites and if the LiDAR system could penetrate overhanging vegetation effectively. Trees, shrubs, cattails, and other aquatic vegetation can obscure water from aerial photography and most of our habitat mapping does not have understory topographical information. Therefore, with the fluctuation of water levels in a given year, MMCD staff would have to physically enter the sites to conduct surveillance work. Primarily staff would use personal experience and employee knowledge to know where to go within the habitat to find water. By using detailed topographical mapping, staff may be able to conduct their work more efficiently and possibly reduce the amount of control material used in each site.

Frontier Precision's demonstration unit (YellowScan Mapper+) was not working properly and had to be serviced. This issue significantly delayed our proposed evaluation. When the unit became available, we were not able to conduct our original trial and evaluated a small wetland area to test the unit's capabilities. The information produced was a higher resolution map than available state maps, but did not answer our original questions. MMCD will work with the vendor to conduct a second trial on desired habitat in 2024. It may be valuable to physically survey multiple sites to directly compare to aerial LiDAR-derived data.

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 collect their empty plastic containers at their facility and package them in large plastic bags for recycling. Low mosquito numbers, and the fact that most control materials now come in bulk containers, significantly reduced the number of jugs generated in 2023. The District did not utilize the ACRC program and will save empty containers for proper disposal in 2024.

The District also 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, thus reducing the District's overall generation of waste products.

Recycling Insecticide Pallets In 2023, MMCD produced over 334 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* and VectoLex® FG 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.

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 2023, Central Life Sciences shipped Altosid® P35 granules (104,600 lb) in 86 totes and reduced the packaging by 2,615 bags. Valent sent MetaLarv® granules (55,000 lb) in 55 bulk totes and reduced the packaging by 1,100 bags. Clarke shipped Natular® G30 granules (62,400 lb) in 38 totes and reduced the packaging by 1,565 bags. Staff were able to spend less time dealing with waste, and the District eliminated 5,280 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 the past eight years, Valent BioSciences agreed to take back all of their products' waste packaging. Due to the quantity of *Bti* and VectoLex® FG granules used (533,832 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 18,321 lb was eliminated from the waste stream.

In 2023, Valent BioSciences was asked about progress in utilizing the waste bags that we return to the Valent facility in Osage, Iowa. Valent admitted that they had not found a suitable method to recycle these multi-layered bags and are currently shipping them to a waste facility in Iowa. MMCD staff did not want to continue to ship our waste to another state and pass on our waste issues to their citizens. Therefore, MMCD will dispose of these unrecyclable insecticide bags in our waste removal processes. Staff will attempt to keep these bags out of landfills, and instead direct them to garbage burner facilities where some public benefit of the generated waste can be realized.

Valent met with MMCD staff to review this large waste issue and proposed some solutions. They are attempting to produce a recyclable or more biodegradable bag. MMCD is attempting to stay out of the waste processing cycle (collection, processing, storage, shipping) and does not have local facilities that accept pesticide waste. Valent is willing to work with our sustainability team to address this issue.

2024 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 quality data. We will continue to improve our calibration techniques to optimize all our mosquito control equipment. We will review spring helicopter treatments to explore options to improve control. Dependent upon the outcome of workgroup recommendations, options may include changes in application rates, review of other control material options and use patterns, changes in flight parameters, or additional workgroup recommendations.

Due to three consecutive years of drought, evaluations of residual control materials have been hindered by the lack of suitable wet habitat to conduct duration studies. MMCD will continue to evaluate environmental conditions in which to conduct longer-term control materials testing. Many duration studies take significant effort to set-up and monitor. MMCD may refrain from attempting to conduct control material research until a more normal weather pattern returns. If, however, habitat conditions are favorable we will continue to evaluate VectoBac® GS granules, CENSOR® G granules, Duplex™-G granules, and Natular® G30 granules. We will focus on efficacy evaluations of current operational materials.

MMCD will continue to expand our drone program and find ways to use this technology effectively. MMCD will be reviewing a larger capacity drone (Agras T20P) to see if that opens some additional advantages to our program. Besides control material applications, we will continue to evaluate LiDAR, photogrammetry, and geographic mapping of mosquito habitat to provide new insights into our field operations.

Chapter 7 Supporting Work

2023 Highlights

- Created two new seasonal positions for UAS (drone) pilots, total now four
- Number of larvicide treatments from a drone in regular operations doubled
- Continued major upgrade of field data system software interface, focusing on mobile forms first
- Using Mobile Map for map-centric data entry
- Public Web Map use hit a new monthly high in May
- Calls requesting adult treatment were low again with low numbers of mosquitoes
- Many public events returned, and school visits expanded

2024 Plans

- Continue to expand drone-based control applications
- Finish major upgrade of data system interface, including reports, and Customer Call and Helicopter Tracking software.
- Expand use of internal wiki for documentation, training, and IPM info
- Continue consultations on northern long-eared bat and prepare for addressing other endangered species concerns

2023 Projects

Unmanned Aircraft Systems (Drones)

Unmanned aircraft systems (UAS) are used by many mosquito control agencies to check 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.

MMCD received our first COA (Certificate of Waiver or Authorization) from the FAA in 2020 which granted us the ability to apply control materials from a treatment drone. Multiple full-time staff members are certified as UAS pilots under the FAA's Part 107 regulation for commercial use drones. In addition, three obtained their Category B license (pesticide application with an aircraft) to treat sites via UAS in Minnesota.

In 2023, we continued to use our three, small quadcopters (Fig. 7.1) to update aerial photos in areas of recent construction and to investigate some wetlands difficult to explore on foot. They have also been used to make internal videos, take staff photos, and inspect unusual mosquito habitats like unmaintained swimming pools and water accumulating on rooftops.

Figure 7.1 DJI Mavic drone

We hired four seasonal positions (UAS Mosquito Technician) specifically for employees to use the treatment drones. These employees worked under the guidance of our current treatment drone pilots and obtained all necessary certifications to pilot and aerially apply insecticides in Minnesota.

In general, small sites (1-3 acres) were targeted for ground treatments. Some smaller and larger sites that are treacherous or very difficult to gain access were also treated by UAS.

The treatment drones were calibrated for four materials: VectoBac® G, MetaLarv®, Altosid® P35, and VectoLex® (see Chapter 6: Product & Equipment Tests). We used three drones in 2023 for treatments, a PrecisionVision 22, a DJI Agras T10, and a DJI Agras T30 (Fig. 7.2).

Figure 7.2 MMCD's DJI Agras T30 treatment drone.

In 2023, we made more than five times the number of treatments compared to 2022 and applied over 5,000 lb of material (Table 7.1). Staff continue to be enthusiastic about the treatment drones' ability to provide a quality treatment without the physical challenge of ground-based applications, especially in sites with high vegetation.

Table 7.1 Treatments by UAS for Altosid® P35 and VectoLex®, 2020-2023

	Altosid® P35			VectoLex® FG		
Year	No. treatments	Acres treated	Pounds used	No. treatments	Acres treated	Pounds used
2020	34.0	48.19	127.72	29.0	39.50	592.45
2021	114.0	160.55	479.44	18.0	22.34	335.00
2022	228.0	299.53	882.79	29.0	43.47	651.20
2023	1188.0	1579.67	4727.75	39.0	53.88	808.20
4-yr Avg.	391.0	521.99	1554.43	28.8	39.80	596.71

Use of drones can increase efficiency of larval treatments through decreasing staff time in cumbersome sites and replacing costly briquet treatments at hard-to-treat cattail sites. Using drones to treat dangerous sites has safety advantages as well as improving employee morale.

In 2023, we wrote multiple new COAs because they are aircraft specific, and we have multiple treatment drone models. We also received separate COAs for two of the drones to conduct operations above the normal 55 lb limit. Additionally, our drones are registered with MnDOT.

Plans for 2024 We plan to use the three newer treatment drones (a DJI Agras T10, a DJI Agras T30, and a DJI Agras T20P) in 2024 for mosquito larvicide applications. We will retire an older treatment drone (a PrecisionVision 22). In general, we plan to assign a treatment drone to a specific facility, although we will share resources with the entire District. We will continue using photo drones to update aerial imagery and to scout sites as needed. Photo drones provide staff with good practice at operating drones (from mission planning to flying to taking new imagery and incorporating these images into their maps).

Our primary activity for 2024 is continuing site treatments by drone and finding ways to expand the number of treatment pilots in a way that fits with our seasonal technician needs and hiring practices. So far, it appears that hiring dedicated, seasonal staff to operate the treatment drones works very well in practice.

Data Systems & Mapping

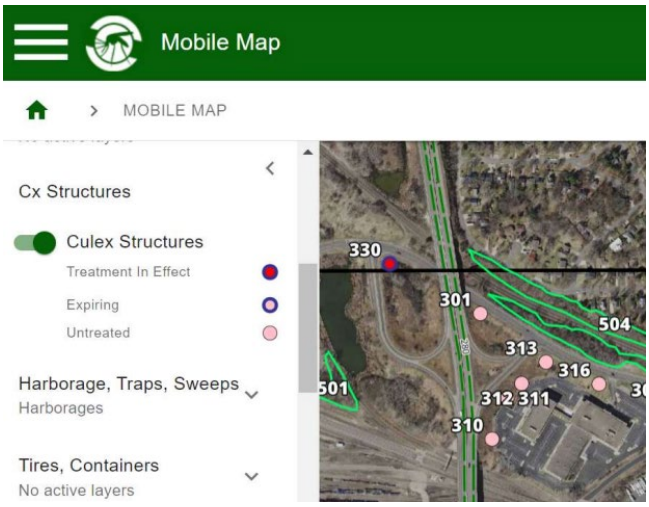


Figure 7.3 Example map from Webster data system. Habitats such as stormwater structures are marked to indicate treatment status.

Our web-based enterprise data and mapping system "Webster" has been developed by Houston Engineering Inc. in conjunction with MMCD staff over the course of the last 18 years and is used daily by all field and lab staff for finding sites, recording work, entering IDs, generating reports, tracking calls, monitoring helicopters and balancing inventory. Its custom design and open-source licensing has fit the needs of MMCD well, but many parts of the user interface were due for an upgrade. In 2022, after evaluating options available, we embarked on a multi-year project to upgrade the system. In 2023, we completed upgrade of the mobile data entry and mapping interfaces, and started upgrading the PC-optimized rainfall maps, reports, lab data entry, and related tools. We expect to complete upgrading those portions in 2024 as well as virus test entry, control material inventory, public call tracking, helicopter track management, and reports linked to maps.

- The new mobile interface is "map-centric" building on the previous success of the Mobile Map developed in 2022. Users can see where they are on the map and start data entry based on the site they are near. Overall, this has reduced entry errors and speeded entry. Users appreciate the wide range of info available through the map.
- The catch basin treatment recording system developed last year was further revised and upgraded to manage the 300,000 treatment records, based on input from users.
- Staff continued expanding use of QGIS, our open source desktop mapping software, to access data in the Webster cloud database. Field staff were able to share maps of sites to be checked with staff assisting from other facilities, without having to drive long distances to exchange paper maps.

Internal Wiki We continued working on an internal wiki to make it easier to store, manage, share, find, and update information about MMCD data systems and other topics within MMCD. Content and access expanded in 2023, and we continue to expand the number of internal authors making updates. As we continue to deal with retirements and staff turnover, we hope it will aid in knowledge transfer and retention.

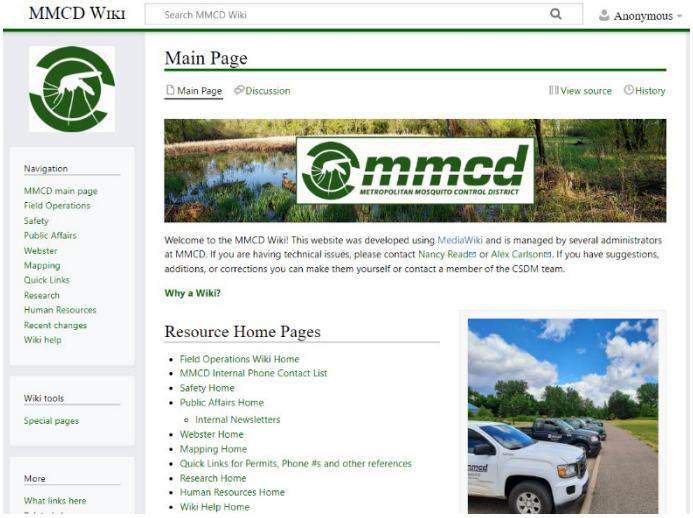


Figure 7.4 MMCD internal wiki

Public Web Map MMCD's public access map on https://mmcd.org/district-maps/ continues to let people see wetland inspection and treatment activity on over 80,000 sites in real time and access history back to 2006. Inspection and treatment information is updated automatically from our data system. Web stats showed 12,376 views, a big increase over previous years, similar to that seen for calls (discussed below). Most of 2023's web map visits came in May where we tracked 7,671 views, which is by far the highest for any single month since the new website launched in Fall of 2019.

GIS Community MMCD staff participate in the MetroGIS collaborative, and we benefit from work by many other units of government. We continue to use access to recent spring aerial photos provided by metro-area counties for our wetland mapping. MMCD uses basemap and geocoder services from the Metropolitan Council and share our wetland data through MnGeo's Geospatial Commons.

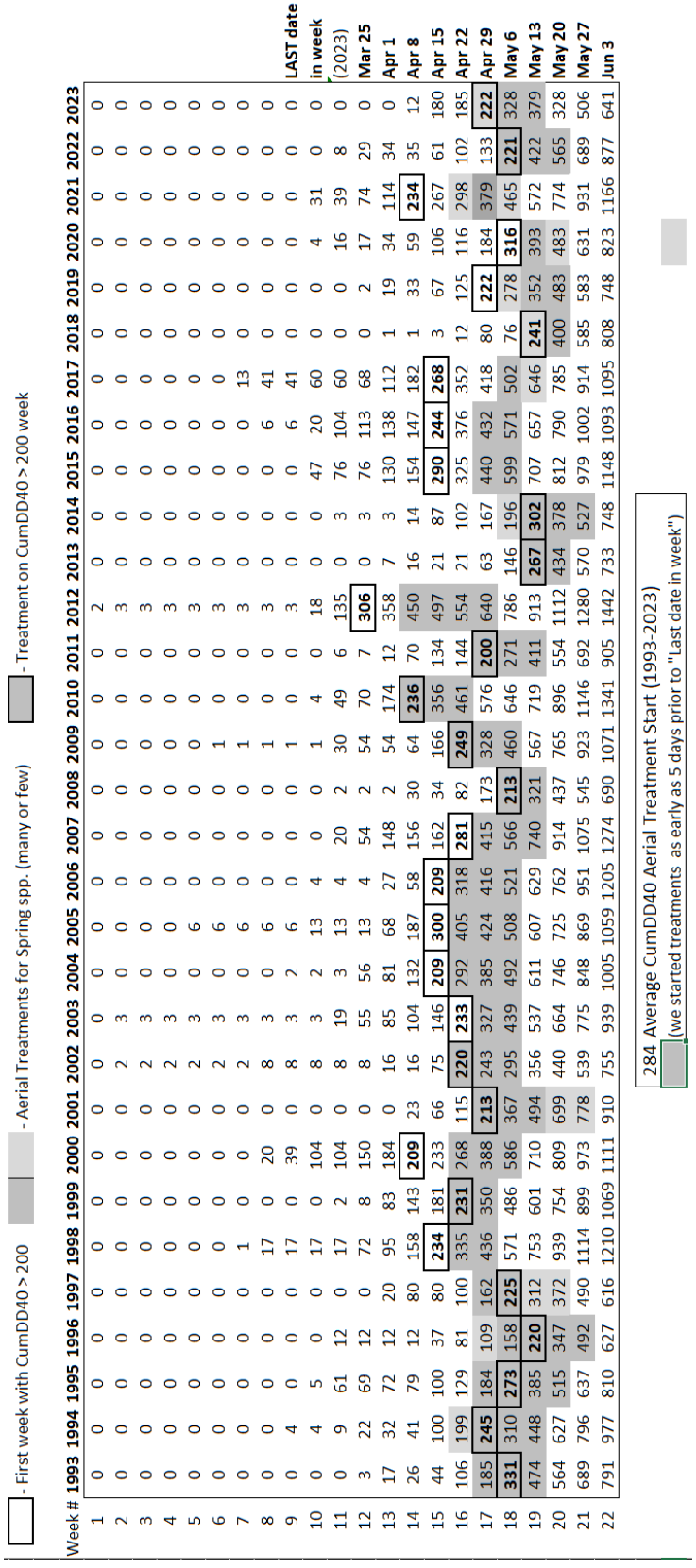
Spring Degree Day Study

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

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

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 1993-2023. 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 2023, the DD_{40F} total went over 200 in week 17 (ending April 29), only 1 week later than the median for the last 20 years. Temperatures stayed warm after that. Aerial treatments for spring *Aedes* (gray boxes) started that week and were completed by May 13. Aerial treatments are not started until a sufficient number of sites are over threshold, seasonal technicians are hired, and helicopters have been calibrated.



Week #	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	LAST date in week (2023)
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	
2	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	
3	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	
4	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	
5	0	0	0	0	0	0	0	0	0	2	3	0	6	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	
6	0	0	0	0	0	0	0	0	0	2	3	0	6	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	
7	0	0	0	0	0	1	0	0	0	2	3	0	6	0	0	0	1	0	0	3	0	0	0	0	13	0	0	0	0	0	0	
8	0	0	0	0	0	17	0	20	0	8	3	0	6	0	0	0	1	0	0	3	0	0	0	0	41	0	0	0	0	0	0	
9	0	4	0	0	0	17	0	39	0	8	3	2	6	0	0	0	1	0	0	3	0	0	0	0	0	6	41	0	0	0	0	**Mar 25**
10	0	4	5	0	0	17	0	104	0	8	3	2	13	4	0	0	1	4	0	18	0	0	0	47	20	60	0	0	0	4	31	0	0	**Apr 1**
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	0	16	39	8	0	**Apr 8**
12	3	22	69	12	0	72	8	150	0	8	55	56	13	4	54	2	54	70	7	**306**	0	3	76	113	68	0	2	17	74	29	0	**Apr 15**
13	17	32	72	12	20	95	83	184	0	16	85	81	68	27	148	2	54	174	12	358	7	3	130	138	112	1	19	34	114	34	0	**Apr 22**
14	26	41	79	12	80	158	143	**209**	23	16	104	132	187	58	156	30	64	**236**	70	450	16	14	154	147	182	1	33	59	**234**	35	12	**Apr 29**
15	44	100	100	37	80	**234**	181	233	66	75	146	**209**	**300**	**209**	162	34	166	356	134	497	21	87	**290**	**244**	**268**	3	67	106	267	61	180	**May 6**
16	106	199	129	81	100	335	**231**	268	115	**220**	**233**	292	405	318	**281**	82	**249**	461	144	554	21	102	325	376	352	12	125	116	298	102	185	**May 13**
17	185	**245**	184	109	162	436	350	**388**	**213**	243	327	385	424	416	415	173	328	576	**200**	640	63	167	440	432	418	80	**222**	184	379	133	**222**	**May 20**
18	**331**	310	**273**	158	**225**	571	486	586	367	295	439	492	508	521	566	**213**	460	646	271	786	146	196	599	571	502	76	278	**316**	465	**221**	328	**May 27**
19	474	448	385	**220**	312	753	601	710	494	356	537	611	607	629	740	321	567	719	411	913	**267**	**302**	707	657	646	**241**	352	393	572	422	379	**Jun 3**
20	564	627	515	347	372	939	754	809	699	440	664	746	725	762	914	437	765	896	554	1112	434	378	812	790	785	400	483	483	774	565	328	
21	689	796	637	492	490	1114	899	973	778	539	775	848	869	951	1075	545	923	1146	692	1280	570	527	979	1002	914	585	583	631	931	689	506	
22	791	977	810	627	616	1210	1069	1111	910	755	939	1005	1059	1205	1274	690	1071	1341	905	1442	733	748	1148	1093	1095	808	748	823	1166	877	641	

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

Evaluating and Reducing Nontarget Risks

Previous Nontarget Work At the direction of the TAB, MMCD has done studies over the years on possible nontarget effects of the control materials we use. Studies on Natular® (spinosad) in vernal pools and cattail marshes done in 2014-2015 have been discussed in previous Annual Reports, and a publication based on that work was released in 2021. Earlier publications and reports on the 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 website at https://mmcd.org/non-target-impact-studies/ and web use stats show it was downloaded 119 times in 2023 (about the same rate as most previous years).

Pollinators and Mosquito Control Pollinator populations (e.g., honeybees, native bees, butterflies, flies, beetles, etc.) are a matter of concern, and MMCD continues efforts to minimize negative effects on pollinators. Our larval control materials pose no risk to bees. The pyrethroids we sometimes use as fog or vegetation spray to control adult mosquitoes have label restrictions that protect pollinators and, when used correctly, are relatively low risk for bees. Staff are trained to recognize areas where pollinators may be active so they can adjust operations to minimize exposure. Beekeepers register hives through "BeeCheck", and in our Pesticide Applicator Training for Certification we train our staff to check for those hives on DriftWatch (https://mn.driftwatch.org/map). MMCD staff watch for hive locations when doing field work and modify adulticide treatments as needed.

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

Monarch Butterfly - In December 2020, the FWS announced that the monarch was a candidate for listing under the Endangered Species Act, and its status would be reviewed annually. MMCD continues to be in active conversation with Monarch Joint Venture (MJV), a national nonprofit partnership of agencies and organizations working to protect monarch migration across the U.S. In 2023, MMCD staff spoke at the MJV annual meeting and provided information on MMCD operations in relation to monarch protection.

Northern Long-eared Bat - In December 2022, the FSW listed the northern long-eared bat (*Myotis septentrionalis*) as endangered under the Endangered Species Act. MMCD started consulting with the FSW in order to determine any potential impacts MMCD's control operations may have on the health of the northern long-eared bat. A complete list of the insecticides authorized for use by MMCD was supplied, and we are currently awaiting further consultation.

MMCD staff participated in the 2023 Pollinator Festival in St. Paul's Bruce Vento Park. We stay in communication with organizations such as the Beekeepers Association and MJV to update information and practices 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 https://www.pca.state.mn.us/water/pesticide-npdes-permit-program. The checklist for mosquito control permits is given at https://www.pca.state.mn.us/sites/default/files/wq-wwprm9-05b.pdf.

MMCD's Pesticide Discharge Management Plan (PDMP), first submitted in 2011, describes contact people, target pests and data sources, thresholds and management, and steps to be taken to respond to various types of incidents. 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 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." An annual analysis of adult mosquito counts around the MVNWR is done by MMCD staff based on the CO_2 trap locations in Figure 7.6.

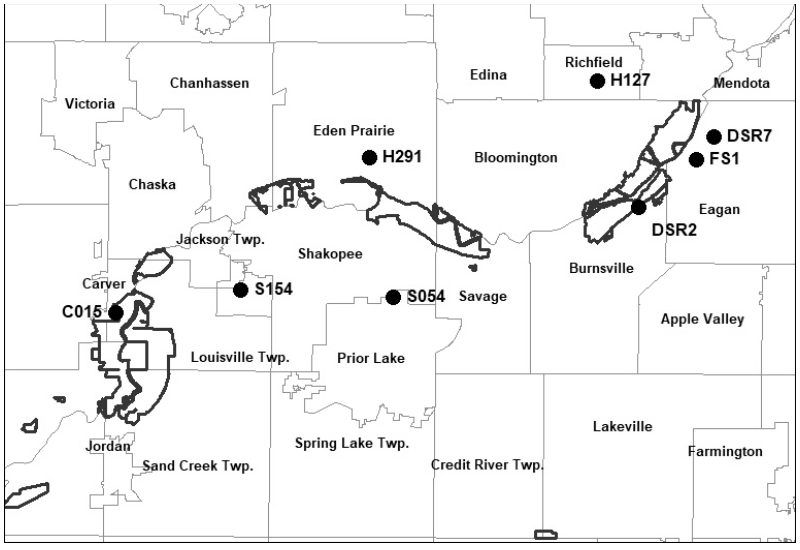


Figure 7.6 CO_2 trap locations (circles) near the Minnesota Valley National Wildlife Refuge. Solid, black lines delineate refuge boundaries.

Culex pipiens and *Cx. restuans* serve as the enzootic or maintenance vectors of 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 pipiens* and *Cx. restuans* populations do not rely on frequent rainfall and these species tend to thrive during drought. Even though CO_2-baited light traps collect low numbers of these two species, they were consistently found in most traps monitored near MVNWR. Two traps had season mean collections in excess of 5.0 per trap (FS1 and H291); both traps are more than ½ mile from the refuge. Larval habitats for these species include wetlands, stormwater management structures, and back yard containers. The mosquitoes likely originated near the traps where they were captured as both species have relatively short flight ranges.

The primary target species for surveillance on the MVNWR is *Culex tarsalis,* a competent vector of WNV to humans. *Culex tarsalis* adult captures across most of the MMCD service area were very low in 2023, with a season average of 0.33 per CO_2-baited light trap. The season's mean collection in traps near MVNWR was higher at 0.60, which is still exceptionally low compared to other years. Trap H291 averaged 2.1 *Cx. tarsalis* per collection night for the season, and no other trap averaged more than one *Cx. tarsalis*. Larval habitats for this species tend to be larger wetlands with grassy borders where water stands for more than one week. The adult flight range is much farther than that of *Cx. pipiens* or *Cx. restuans.*

Mean collections of *Aedes vexans* near MVNWR in CO_2-baited light traps were lower than during most years due to dry conditions. The peak rate of capture occurred on June 6 at 906.9 per trap. Average collections of *Ae. vexans* exceeded 100 only four times – the four consecutive surveillance dates from May 31 to June 21. Collections of *Ae. vexans* were greatest within one mile of the refuge.

Mosquitoes collected from traps near MVNWR were tested for WNV from the last week of May through the second week of September. There were four WNV positive samples from the area in 2023. All four WNV positive samples were mixed pools of *Cx. pipiens* and *Cx. restuans*. Two were from the FS1 location on August 1 and August 22, and two were from the DSR7 location on August 15 and August 22. This is more than 2022 but the same as 2021.

Because the *Cx. tarsalis* population remained low and drought conditions persisted in 2023, MMCD did not request permission to conduct larval mosquito surveillance within the MVNWR.

Integrated Pest Management Plans

As part of MMCD's 2021 internal reorganization we re-focused on integrated pest management (IPM) and developed species-specific IPM plans as a way to:

- Ensure a common understanding of what we do and why
- Show the basis for our surveillance and control practices
- Help discover what's going well and what to improve

The plans' structure was based on state and national pesticide applicator training, AMCA "Best Practices," and basic problem-solving steps. Each plan documents the information needed to understand a pest problem and develop and evaluate control strategies. We also have a brief "Pest Alert" format (Fig. 7.7) for training new staff.

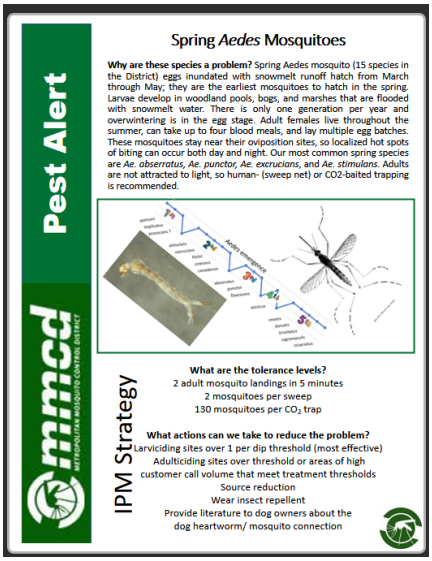


Figure 7.7 IPM Pest Alert

Each species group plan covers the following questions:

1. Why is this species (or group) a problem?
2. What are the tolerance levels?
3. Where and when are those levels exceeded
4. What action can we take to reduce the problem? (and not cause more problems)
   - Public Education
   - Prevention
   - Treatment (action thresholds, dose, targeting, timing, materials, resistance)
5. How do we know we've reduced the problem, and show that to the public?

The plans are designed to promote communication, encourage staff to explore new solutions, and evaluate effectiveness.

Plans were developed for the following species groups: Spring *Aedes*, Floodwater Mosquitoes, Cattail Mosquito, Vector Mosquitoes (container *Aedes*, *Culiseta melanura, Culex restuans/pipiens, Cx. tarsalis, Cx. salinarius*), Black Flies (*Simulium johannseni, S. luggeri, S. meridionale, S. tuberosum, S. venustum*) and Ticks (*Ixodes scapularis*).

Staff hold annual pre- and post-season Operations meetings to review the status of IPM and issues encountered for each of the species groups. We continue to work on ways to evaluate and improve our programs. In 2023 we started incorporating the plans in the internal wiki to make them more accessible to all staff.

Public Communication

Notification of Control The District continues to post daily adulticide information on its website and e-mail notification is available through GovDelivery. Aerial larvicide treatment schedules (helicopter activity) are also posted on the website and posted on Twitter/X, Facebook, and NextDoor.

Calls Requesting Service High numbers of human-biting mosquitoes in May and early June coincided with the highest number of mosquito annoyance calls that the District has experienced in several years. This was followed by dry conditions in July, August, and September which led to a decline in calls from residents. In 2023, the number of annoyance calls peaked the week of May 22, which was one week prior to the peak of mosquitoes collected in sweeps on May 30 (Figure 7.8).

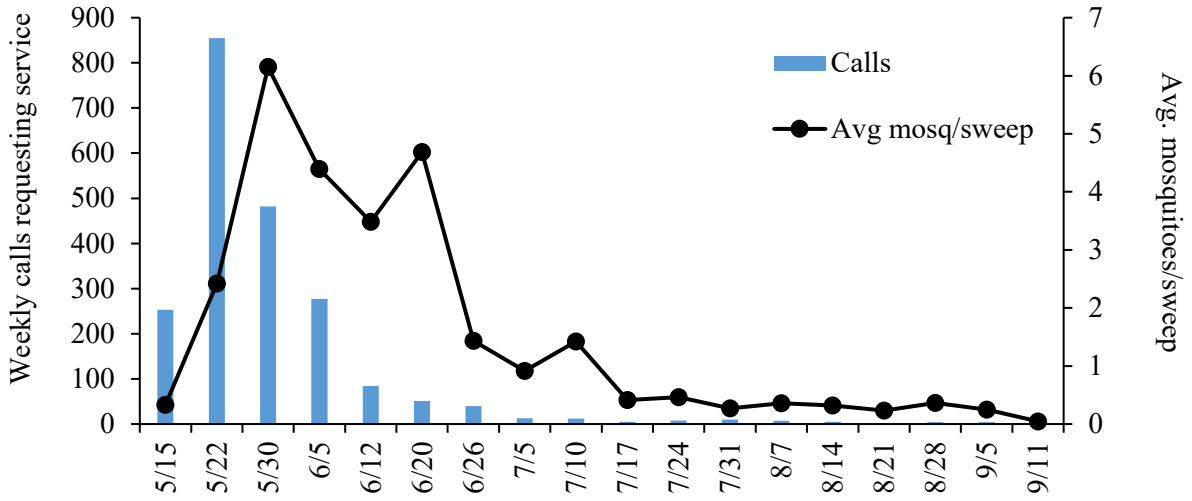


Figure 7.8 Calls requesting service and sweep net counts, by week, 2023.

Calls to report adult mosquito annoyance in 2023 were at their highest since 2016 (Table 7.2) and significantly higher than the past two years of 2021 and 2022. The majority of the 2023 calls came from the one-month period between May 15 and June 15 which accounted for 1,414 of the season's 1,522 mosquito annoyance reports. Calls to request tire pickups reached a 10-year high in 2023 with more residents throughout the District accessing this service. Requests for treatments at public events and requests for limited or no treatment remained at similar levels to the previous year.

Table 7.2 Yearly call totals (including emails) by service request type, 2013-2023

	Number of calls by year										
Service request type	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Check a larval site	609	1,068	447	886	1,151	601	802	438	234	472	684
Report adult mosquito annoyance	1,825	2,454	1,633	2,499	1,157	1,212	1,144	1,030	176	384	1,522
Public event, request treatment	70	93	91	105	101	91	71	12	43	61	64
Request tire removal	351	429	366	377	363	325	411	411	374	377	534
Request limited or no treatment	[a]136	[b]146	139	158	126	75	69	76	73	79	87

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

Website In 2019, MMCD launched a revised website with more information and improved systems for interactions with the public. In 2023, mmcd.org had 76,728 unique visitors which was up from 44,735 in 2022.

In 2021, a new contact form was implemented on the MMCD website called "Submit a Tip" where residents can submit informational items or requests for service that are then routed directly to field staff through the MMCD call system. This form saw expanded use in 2023 with 1,560 service requests which was much higher than the 337 requests that came in 2022.

Community and School Presentations MMCD continued to expand our educational offerings in 2023 in the form of in-person presentations delivered to schools and community groups. Throughout 2023 we delivered classroom presentations to 22 schools across the District serving elementary, middle, and high school students. We participated in large educational events like the Children's Water Festival in St. Paul and STEM Night for District 196 in Apple Valley.

Public Events MMCD's attendance at events continued to increase in 2023 including a few new occasions. The biggest event of the year was the Minnesota State Fair where District staff had conversations with over 9,600 people during the 12-day event. MMCD also attended county fairs in Anoka, Dakota, Carver, Scott, and Washington counties and added new events like Grand Old Day in St. Paul and the Great Minnsect Show at the University of Minnesota. We participated in 21 parades throughout the District in 2023 where we featured our mosquito mascot "Vectoria."

Figure 7.9 MMCD staff delivering presentations at New Prague schools (left) and the Children's Water Festival (center). MMCD's booth at Grand Old Day in St. Paul (right).

Social Media As part of an ongoing effort to notify residents when and where treatment is to take place, provide fun and educational information, and create another point of contact with the District, MMCD has maintained a presence on Facebook, Twitter, and Instagram. MMCD currently has 1,049 Twitter followers, up from 938 followers at the end of 2022; 1,923-page followers on Facebook, up from 1,779 in 2022; and 532 followers on Instagram, up from 401 at the end of 2022.

MMCD also uses GovDelivery to give advance notification to District residents of adult mosquito treatments, and to distribute press releases and make announcements about job openings. At the end of 2023 there were 9,729 individual subscribers who opted in to receive some sort of communications from MMCD, which is up from 8,928 at the end of 2022.

Sustainability Initiative

MMCD's Sustainability Initiative began in 2013 and examined the economic, environmental, and social impacts of adopting sustainable practices throughout District operation. Our Sustainability Team led many efforts and brought suggestions to other teams. Efforts included:

- reducing energy usage through actions like LED lighting, fleet vehicle options, work-from-home and virtual meetings;
- reducing waste through bulk control material packaging, composting, and recycling;
- using renewable energy at six of our seven facilities through solar garden subscriptions; and
- promoting social responsibility and wellness through community donation programs.

Some activities were scaled back during COVID-19, but many processes developed in previous years were carried forward. In 2024 we plan to review our sustainability efforts and make plans for what could be the next steps.

Professional Association Support

American Mosquito Control Association MMCD staff members continued to provide support for the national association. Kirk Johnson is on the Federal Lands Subcommittee of the Legislative and Regulatory Committee. Diann Crane recorded the Adult Surveillance module for AMCA's virtual training on best practices for integrated mosquito management. The goal of this training program is to teach people new to the field how to perform science-based mosquito control.

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. Weekly conference calls with regional partners allow for the dissemination of trends in vector populations and for relaying results of research. In 2023, Scott presented to the group about MMCD's adult mosquito surveillance network emphasizing our unique sweep net collections, and Kirk presented on impacts of climate change and extreme weather events. Scott has provided cattail mosquito predictions for other members of the group using our predictive model. We have learned about underground larval habitat management from group participants from the Chicago area.

North American Black Fly Association John Walz served as President and Carey LaMere maintained the association's website, https://nabfa.org/. The 2023 NABFA meeting was February 7-10, 2023 in Flemington, NJ.

North Central Mosquito Control Association Mark Smith and Scott Larson served on the Board of Directors of this regional association for Minnesota, North Dakota, South Dakota, Wisconsin, Iowa, and the central provinces of Canada (http://north-central-mosquito.org/). There was no annual meeting held in 2023. In the past, attending the meeting qualified attendees for pesticide applicator recertification for Minnesota and North Dakota, so this year MMCD staff attended other recertification workshops.

Scientific Publications, Presentations, and Posters

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 2023 and talks that are planned in 2024.

Publications
No publications in 2023.

2023 Presentations & Posters

LaMere, C.L. 2023. *Simulium tuberosum*, the newest biting gnat problem in the greater Minneapolis-St. Paul area. North American Black Fly Association Annual Meeting, February 9-10, (Flemington, NJ).

Larson, S.R. 2023. Program highlights and current operations at the Metropolitan Mosquito Control District. Annual Meeting of the Michigan Mosquito Control Association, February 2, 2023 (East Lansing, Michigan).

Read, N. and A. Sheppard, 2023. Start with a map for better field data entry. Minnesota GIS/LIS Conference, October 12, 2023 (Duluth, Minnesota).

Smith, M. 2023. Overview of the Metropolitan Mosquito Control District's *Coquillettidia perturbans* control program. Annual Meeting of the American Mosquito Control Association, February 27-March 3 (Reno, Nevada).

Smith, M. 2023. Overview of applied research at the Metropolitan Mosquito Control District. Annual Meeting of the American Mosquito Control Association, February 27-March 3 (Reno, Nevada).

Walz, J. 2023. MMCD black fly program history and overview. North American Black Fly Association Annual Meeting, February 9-10, (Flemington, NJ).

2024 Presentations & Posters

Guenther, C. and S. Partyka 2024. Expanding drone field operations. In: UAS Ops in Mosquito Control Symposium. Annual Meeting of the American Mosquito Control Association, March 4-8 (Dallas, Texas).

Elling, J. and J. Kirkman 2024. Metropolitan Mosquito Control District unmanned aircraft systems larvicide program. In: UAS Ops in Mosquito Control Symposium. Annual Meeting of the American Mosquito Control Association, March 4-8 (Dallas, Texas).

LaMere, C.L. 2024. MMCD Black Fly Program update. North American Black Fly Association Annual Meeting, February 7-9 (Harrisburg, PA).

McMillan, J. and S. Larson 2024. Aligning data streams for (successful) entomological evaluations of larviciding for control of *Culex* mosquitoes in Minneapolis-St. Paul, Minnesota. Annual Meeting of the American Mosquito Control Association, March 4-8 (Dallas, Texas).

Crane, D. and C. LaMere. 2024. Efficacy and nontarget effects of a spinosad-based larvicide in Minnesota vernal pools and cattail marshes. In: What Have We Learned: A Conversation on 15 Years of Spinosad Use in Public Health Symposium. Annual Meeting of the American Mosquito Control Association, March 4-8 (Dallas, Texas) (Presented by S. Larson).

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 1965-2023
APPENDIX C	Total Number of Mosquitoes by Species Collected in 15 Long-term CO_2 Traps, 2023
APPENDIX D	Description of Control Materials
APPENDIX E	2023 Control Materials: Percent Active Ingredient (AI), AI Identity, Per Acre Dosage, AI Applied Per Acre, and Field Life
APPENDIX F	Acres Treated with Control Materials Used by MMCD for Mosquito and Black Fly Control for 2015-2023
APPENDIX G	Graphs of Larvicide, Adulticide, and ULV Fog Treatment Acres, 1984-2023
APPENDIX H	Control Material Labels
Appendix I	Technical Advisory Board Meeting Notes

APPENDIX A Mosquito and Black Fly Biology and Species List

Mosquito Biology

There are 53 species of mosquitoes in Minnesota, although one species is introduced yearly via the tire trade. Forty-five species are detected regularly 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 common 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) stimulates 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. The 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 *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.

Culiseta inornata and *Anopheles quadrimaculatus* are notable permanent water species in our area. *Culiseta inornata* is one of the first mosquitoes seen in the springtime. They are quite large and will leave their hibernacula in search of a bloodmeal on warm spring days. While they are normally reluctant to feed on humans, they will do so in the spring. Resident reports of mosquitoes in March and April are usually *Cs. inornata*.

Anopheles quadrimaculatus was relatively rare in our area until the early 2000s, when we documented an uptick in their population. It is now considered common here. The type location (first time a species was identified) is Wabasha, MN. In southern states this species transmits malaria, and although we had malaria in our area in the early 20th century, there have been no locally transmitted instances of malaria in Minnesota.

Rare Species or Invasive

Orthopodomyia signifera is a treehole and container-breeding mosquito that is rarely encountered in collections made by MMCD. *Aedes albopictus*, discussed above, is an invasive species that almost certainly cannot overwinter in the District and is reintroduced 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 the water temperature. The 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 conducted 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.

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

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 horses 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.

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Species Code and Significance/Occurrence of the Mosquitoes in the Metropolitan Mosquito Control District, Those in Northern Minnesota, and Incidental or Unverified Species

Code	Genus	species	Significance, Occurrence, Disease
Mosquitoes			
1.	*Aedes*	*abserratus*	common, spring
2.		*atropalpus*	rare, summer
3.		*aurifer*	rare, spring
4.		*euedes*	very rare, spring
5.		*campestris*	very rare, spring
6.		*canadensis*	common, spring-summer
7.		*cinereus*	ubiquitous, spring-summer
8.		*communis*	very rare, spring
9.		*diantaeus*	very rare, spring
10.		*dorsalis*	uncommon, spring-summer
11.		*excrucians*	ubiquitous, spring
12.		*fitchii*	common, spring
13.		*flavescens*	very rare, spring
14.		*implicatus*	uncommon, spring
15.		*intrudens*	very rare, spring
16.		*nigromaculis*	rare, summer
18.		*punctor*	common, spring
19.		*riparius*	common, spring
20.		*spencerii*	rare, spring
21.		*sticticus*	common, spring-summer
22.		*stimulans*	ubiquitous, spring
23.		*provocans*	uncommon, early spring, JCV
24.		*triseriatus*	common, summer, LAC
25.		*trivittatus*	common, summer
26.		*vexans*	ubiquitous, #1 summer species
50.		*hendersoni*	uncommon, summer
51.		*albopictus*	uncommon, invasive, vector[1]
52.		*japonicus*	common, summer, LAC
118.		*abserratus/punctor*	inseparable when rubbed
261.	*Ae.* unidentifiable		
262.	Spring *Aedes* (adult samples only)		
263.	Non-*vexans Aedes* (larval airwork)		
264.	Summer *Aedes* (adult samples only)		
Other Minnesota species			
17.	*Aedes*	*pionips*	very rare, spring, northern MN
53.	*Aedes*	*decticus*	very rare, spring, northern MN
49.	*Wyeomyia*	*smithii*	very rare, northern MN[2]
Incidental			
	Aedes	*cataphylla*	verified[3]
	Culiseta	*impatiens*	unverified

Code	Genus	species	Significance, Occurrence, Disease
27.	*Anopheles*	*barberi*	rare, tree hole
28.		*earlei*	rare[4]
29.		*punctipennis*	common
30.		*quadrimaculatus*	common
31.		*walkeri*	common
311.	*An*. unidentifiable		
32.	*Culex*	*erraticus*	uncommon[5]
33.		*pipiens*	ubiquitous, WNV
34.		*restuans*	ubiquitous, WNV
35.		*salinarius*	uncommon, WNV
36.		*tarsalis*	common, WNV
37.		*territans*	ubiquitous
371.	*Cx*. unidentifiable		
372.	*Cx.*	*pipiens/restuans*	when inseparable
38.	*Culiseta*	*inornata*	ubiquitous
39.		*melanura*	uncommon, EEE
40.		*minnesotae*	common
41.		*morsitans*	uncommon
411.	*Cs*. unidentifiable		
42.	*Coquillettidia perturbans*		ubiquitous
43.	*Orthopodomyia signifera*		rare
44.	*Psorophora ciliata*		very rare
45.		*columbiae*	very rare
46.		*ferox*	uncommon
47.		*horrida*	uncommon
471.	*Ps*. unidentifiable		
48.	*Uranotaenia sapphirina*		common, summer
491.	Males (adults)		tallied in NJ traps
501.	Unidentifiable mosquito		
601.	Non-mosquito insect (ex. phantom midge)		

[1]Invasive species introduced yearly through tire trade.
[2]Larvae develop in pitcher plants found in bog habitat in northern Minnesota.
[3]Two *Aedes cataphylla* larvae were collected in April 2008 in Minnetonka.
[4]Last larval collections were in 2012.
[5]Adult collections have been increasing since 2002; larvae are very rarely collected.

Genus Abbreviations for Mosquitoes

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

Occurrence Rankings (number of times collected)

Very rare = 0-9	Common = 1,000-9,999
Rare = 10-99	Ubiquitous = ≥ 10,000
Uncommon = 100-999	

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, 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 Long-term NJ Light Trap Locations and Average May to September Rainfall, 1965-2023. 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
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

Year	Spring *Aedes*	*Aedes cinereus*	*Aedes sticticus*	*Aedes trivittatus*	*Aedes vexans*	*Culex tarsalis*	*Cq. perturbans*	All species	Avg. Rainfall
2010	0.07	0.08	0.06	0.17	16.18	0.23	0.36	26.13	24.66
2011	0.10	0.07	0.11	0.78	33.40	0.07	5.76	47.36	20.61
2012	0.04	0.03	0.15	0.21	21.10	0.04	4.01	30.39	17.53
2013	0.37	0.49	0.15	0.81	26.95	0.12	1.80	35.08	17.77
2014	0.12	0.32	0.19	0.44	32.42	0.20	2.18	41.72	23.60
2015*	0.02	0.26	0.01	0.46	27.73	0.06	3.77	36.00	24.02
2016	0.01	0.03	0.01	1.65	24.53	0.06	4.80	33.44	27.76
2017	0.01	0.08	0.09	0.17	25.71	0.05	9.62	37.85	22.27
2018	0.02	0.04	0.18	0.26	15.21	0.05	1.88	20.76	22.54
2019	0.02	0.03	0.03	0.19	5.86	0.02	0.89	8.27	26.67
2020	0.09	0.05	0.12	0.21	10.52	0.01	3.88	16.49	20.00
2021	0.01	0.00	0.00	0.00	1.37	0.06	0.66	3.79	15.43
2022	0.05	0.14	0.09	0.05	3.45	0.02	0.36	6.09	13.84
2023	0.27	0.35	0.33	0.01	1.19	0.07	0.49	7.85	14.71

*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 Total Number of Mosquitoes by Species Collected per Night in 15 Long-term CO_2 Trap Locations, 2023

	Trap Code, Location, and Number of Collections															
	A120 Ajawah EEE	A183 Innsbruck Park	C013 Watertown	D063 Thompson Co. Pk	D181 Miesville	DSR4 Eureka (Rice Lk)	E001 Stillwater	E004 Forest Lake	H284 Dayton	H291 Eden Prairie	H566 Eagle Ridge	H625 Ft. Snelling Golf	S139 Credit River	S154 Jackson Town Hall	SF02 Grandstand	All
Species	18	16	18	18	18	18	18	17	18	18	17	18	18	18	16	264
Ae. abserratus	501	14	26	0	0	5	12	45	20	1	3	1	4	0	0	632
atropalpus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
aurifer	116	0	0	0	0	0	1	6	4	0	0	0	0	0	0	127
canadensis	679	640	1	2	1	7	13	7	12	2	5	2	1	0	1	1,373
cinereus	3007	1923	786	7	2	619	168	927	1227	51	2442	10	126	70	3	11,368
diantaeus	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
dorsalis	0	0	0	0	0	0	0	5	1	0	1	8	2	0	2	19
excrucians	248	287	35	2	0	6	168	89	245	4	229	8	19	1	5	1,346
fitchii	19	29	0	2	0	3	74	27	5	0	10	3	3	0	1	176
hendersoni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
implicatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
japonicus	0	3	0	1	0	1	0	0	4	1	0	0	0	0	0	10
nigromaculus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
punctor	234	12	8	1	0	7	3	11	3	1	1	1	0	0	0	282
riparius	1	5	0	0	0	1	1	0	16	0	0	0	0	0	0	24
spencerii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
sticticus	46	24	25	379	0	10	33	16	114	17	5	1657	21	10	28	2,385
stimulans	736	506	13	39	0	15	264	368	619	7	394	5	42	2	1	3,011
provocans	139	3	0	2	0	0	10	2	4	0	1	0	0	0	0	161
triseriatus	2	2	0	0	0	1	1	1	0	1	0	8	0	0	0	16
trivittatus	0	40	0	3	2	9	6	0	2	24	22	1	1	3	9	122
vexans	95	574	108	287	1	317	76	59	299	658	520	117	163	24	47	3,345
abserratus/punctor	2,077	39	29	1	0	14	32	73	31	0	15	2	7	0	1	2,321
Aedes unidentifiable	44	30	6	3	0	0	6	19	10	3	29	12	1	0	0	163
Spring *Aedes* unident.	172	131	12	10	0	1	54	47	35	4	178	2	15	3	3	667
Summer *Aedes* uniden	0	9	3	7	0	0	5	6	267	1	3	16	0	1	0	318
An. barberi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
earlei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
punctipennis	214	41	15	11	0	28	20	19	41	80	14	7	20	3	4	517
quadrimaculatus	90	23	19	7	0	66	30	117	120	104	44	15	88	133	0	856
walkeri	129	1	0	0	0	0	0	2	0	5	0	1	0	2	0	140
An. unidentifiable	2	3	0	2	0	2	3	5	6	2	6	0	2	0	0	33
Cx. erraticus	0	0	0	0	0	2	0	0	0	0	0	1	0	2	0	5
pipiens	1	21	14	10	5	7	0	82	19	52	55	63	1	5	31	366
restuans	4	9	0	0	1	10	4	13	13	7	3	7	1	3	4	79
salinarius	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
tarsalis	0	7	3	0	3	38	1	2	6	40	8	32	1	2	11	154
territans	4	1	0	0	0	1	0	1	3	0	0	0	2	2	0	14
Cx. unidentifiable	0	2	0	0	0	0	1	6	1	0	2	0	0	1	0	13
Cx. pipiens/restuans	3	37	12	19	11	19	6	122	25	54	104	55	1	13	33	514
Cs. inornata	4	15	5	4	0	1	2	2	0	2	8	24	14	0	25	106
melanura	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	7
minnesotae	1	0	0	0	1	0	0	0	2	0	1	0	0	1	1	7
morsitans	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Cs. unidentifiable	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Cq. perturbans	1341	182	18	29	0	6	624	169	32	135	118	20	53	15	6	2,748
Or. signifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ps. ferox	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	4
horrida	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Ps. unidentifiable	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ur. sapphirina	1	0	0	0	0	2	5	0	1	0	1	0	0	1	0	11
Unidentifiable	1	2	0	11	0	0	5	2	1	0	2	0	0	0	0	24
Total	9,919	4,618	1,138	839	27	1,198	1,630	2,250	3,189	1,256	4,229	2,078	588	297	217	33,473

APPENDIX D Description of Control Materials Used by MMCD in 2023

The following is an explanation of the control materials currently used by MMCD. The specific names of products used in 2023 are given. The generic products will not change in 2023, although the specific formulator may change.

Insect Growth Regulators

Methoprene 150-day briquet 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 granule Central Life Sciences
Altosid® P35 EPA# 89459-95

Altosid® P35 consists 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. Smaller sites less than 3 acres may be treated with drones at a rate of 3 lb per acre.

Methoprene pellet 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 used at 3 and 4 lb per acre. 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 3-4 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.

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*) corn cob** Valent Biosciences
VectoBac® GS EPA#73049-10

VectoBac® GS is a smaller grit size when compared to VectoBac® G. VectoBac® GS has more granules per pound thus applications produce more granules per square foot than VectoBac® G. This material 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® FG EPA# 73049-20

VectoLex® FG 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. Drones may conduct fall applications at a rate of 15 lb per acre and would be conducted on smaller sites less than 3 acres.

***Bacillus thuringiensis israelensis* (*Bti*) & methoprene granules** Central LifeSciences
Duplex-G® EPA# 89459-93

Duplex-G® granule is a sand formulation containing methoprene and *Bti*. Duplex® may be applied in all types of larval habitat. The combination material controls existing larvae with *Bti* and has a 21 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 8 lb per acre (0.41 lb/acre *Bti* and 0.12 lb/acre methoprene). In evaluations, the material is applied to pockety sites with cyclone seeders or power backpacks. In addition, the material was also applied by helicopter to floodwater sites.

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

Natular® is a sand 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. This product is OMRI listed for use in and around organic farms and gardens. The Natular® granule is formulated on a sand granule base. Natular® G30 is formulated as long-release granules (30-day) and can be applied to dry or wet sites.

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

CENSOR® G is a corn cob formulation of spinosad, a biological toxin extracted from the soil bacterium *Saccharopolyspora spinosa,* that was developed for larval mosquito control. CENSOR® G does not hold the same organic certification as Natular® G30 due to its corn cob carrier. USA suppliers of corn cob cannot guarantee that all cob is GMO free primarily due to pollen transfer via wind currents. CENSOR® G is formulated as a residual 7 day granule that can be applied to dry or wet sites. This product was evaluated (9 lb/ac) in early spring sites due to its cold water activity and multiple modes of action (contact & ingestion) of the active ingredient.

Pyrethrin Adulticides

Natural Pyrethrin Clarke
Merus™ 3.0 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™ can be used by the District to treat adult mosquitoes in known areas of concentration or nuisance where crop restrictions (organic growers) prevent treatments with permethrin 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.

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 5.7 mixture 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 E 2023 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® 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
CENSOR® G	Spinosad	0.60	9 lb	0.0450	7
VectoBac® G	*Bti*	0.20	5 lb	0.0100	1
			8 lb	0.0160	1
VectoBac® GS	*Bti*				
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
VectoLex® WSP***	*Bs*	7.50	0.022 lb** (10 g)	0.0017**	7-28
Duplex-G	*Bti* and methoprene	5.35 *Bti* 1.60 methoprene	8 lb	0.4100 *Bti* 0.1200 methoprene	21 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
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.
** Catch basin treatments—dosage is the amount of product per pouch, catch basins can be treated with one or two pouches.
***Experimental

APPENDIX F Acres Treated with Control Materials Used by MMCD for Mosquito and Black Fly Control, 2015-2023.The actual geographic area treated is smaller because some sites are treated more than once

Control Material	2015	2016	2017	2018	2019	2020	2021	2022	2023
Larvicides									
Altosid® XR Briquet 150-day	186	168	166	167	162	180	141	133	216
Altosid® XR Briquet catch basins (count)	450	448	445	509	476	470	414	316	472
Altosid® Pellet 30-day	31,494	19,173	17,939	10,202	12,020	729	0.16	0	0
Altosid® Pellet catch basins (count)	248,599	240,806	252,694	262,851	265,915	264,399	13,550	0	0
Altosid® P35 30-day	0	0	0	0	0	26,784	26,511	22,068	35,357
Altosid® P35 Catch basins (count)	0	0	0	0	0	11,648	270,810	301,352	316,762
MetaLarv® S-PT +2	21,126	33,409	23,740	23,574	23,003	18,408	19,431	19,295	19,349
Duplex-G *Bti*+Methoprene	0	0	0	0	0	0	0	0	13
Natular® G30 (Spinosad)	8,840	13,023	12,271	15,662	17,277	8,946	19,968	13,468	13,640
CENSOR® G (Spinosad)	0	0	0	0	0	0	0	0	620
VectoLex® FG granules	3,777	6,076	4,773	4,660	5,036	1,858	5,255	4,235	8,537
VectoBac® G *Bti* corn cob granules	258,148	234,120	136,173	134,926	156,089	139,006	78,992	70,309	58,067
VectoBac® GS *Bti* corn cob granules	0	0	0	0	0	0	0	0	6,549
VectoBac® 12 AS *Bti* liquid (gal used) Black fly control	4,351	3,112	3,621	3,234	4,362	4,085	1,172	3,609	1,333
Adulticides									
Permethrin 57% OS Permethrin	6,093	8,128	5,038	3,771	3,367	1,742	113	334	765
Scourge® 4+12 Resmethrin/PBO	19,767	23,072	2,090	0	0	0	0	0	0
Anvil® 2 + 2 Sumithrin/PBO	27,183	16,399	11,683	7,790	3,665	584	257	727	756
Zenivex® Etofenprox	10,380	34,984	23,097	26,918	15,289	4,124	2,166	640	389

APPENDIX G Graphs of Larvicide, Adulticide, and ULV Fog Treatment Acres, 1984-2023

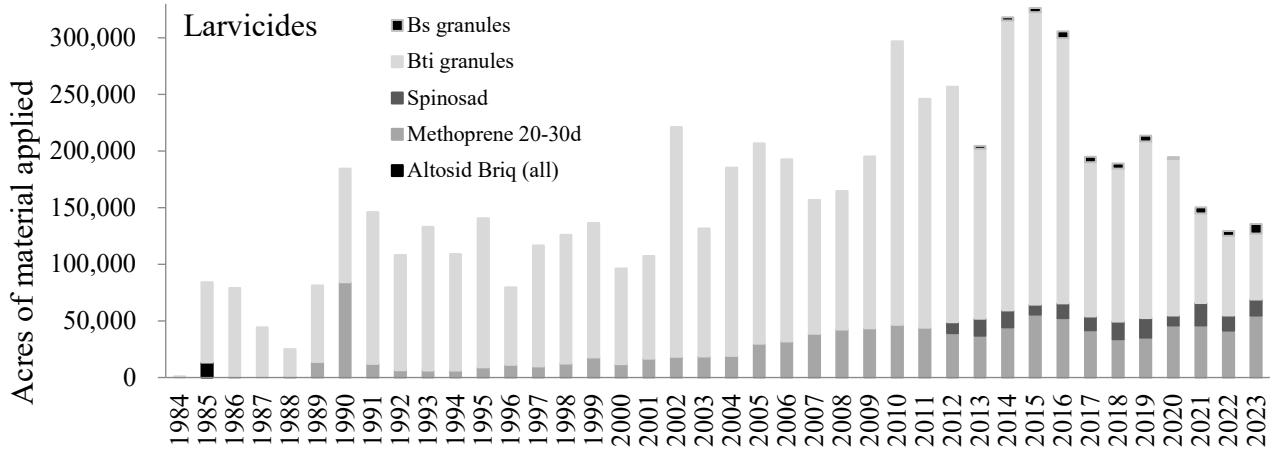

Figure G.1 Summary of total acres of larvicide treatments applied per year since 1984. For materials that are applied to the same site more than once per year, actual geographic acreage treated is less than that shown.

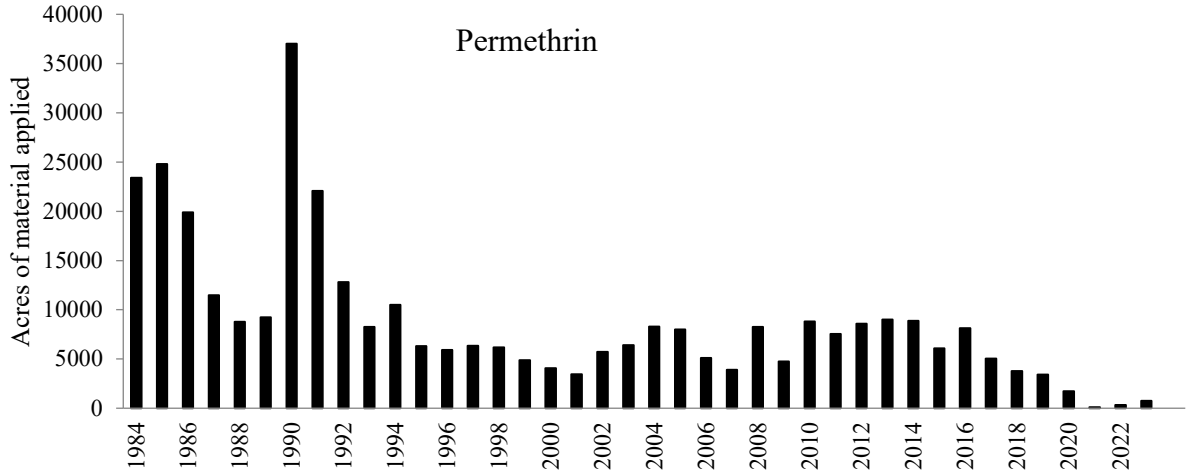

Figure G.2 Summary of total acres of permethrin treatments applied per year since 1984. This material may be applied to the same site more than once per year, so actual geographic acreage treated is less than that shown.

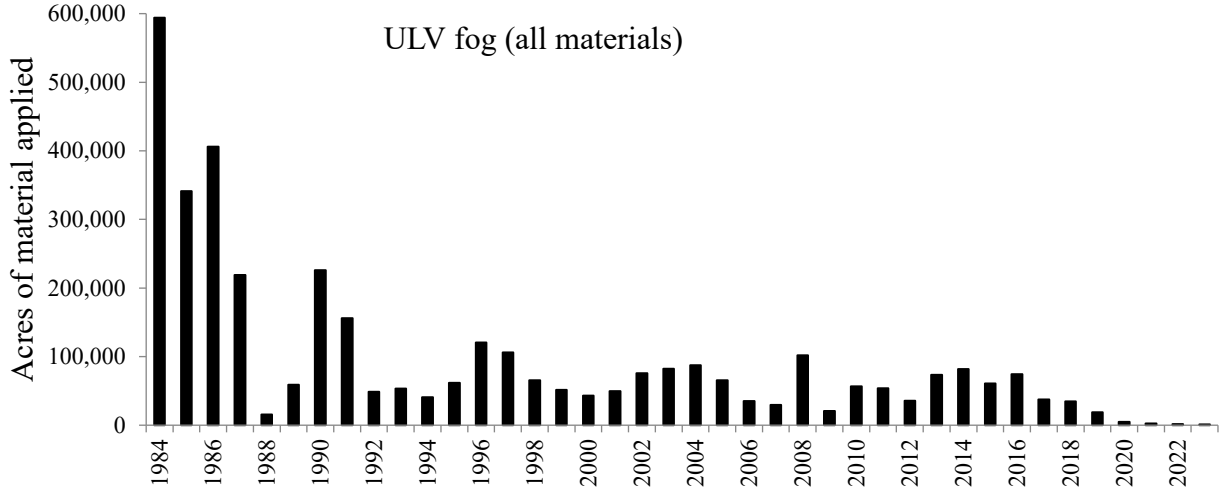

Figure G.3 Summary of total acres of ULV fog treatments applied per year since 1984. This material may be applied to the same site more than once per year, so actual geographic acreage treated is less than that shown.

APPENDIX H Control Material Labels

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

Altosid® P35 (EPA# 89459-95)

Duplex™-G (EPA# 89459-93)

MetaLarv® S-PT (EPA# 73049-475)

VectoBac® 12AS (EPA# 73049-38)

VectoBac® G (EPA# 73049-10)

VectoBac® GS (EPA# 73049-10)

VectoLex® FG (EPA# 73049-20)

Natular® G30 (EPA# 8329-83)

CENSOR® (EPA# 8329-80)

Permethrin 57% OS (EPA# 8329-44)

Anvil® 2+2 ULV (EPA# 1021-167-8329)

Zenivex® E4 RTU (EPA# 2724-807)

Merus™ 3.0 RTU (EPA# 8329-94)

Appendix I MMCD Technical Advisory Board Meeting Notes February 7, 2023

TAB Members Present

Elizabeth Schiffman, MN Department of Health (in person)
Steve Kells, University of Minnesota (in person)
John Moriarty, Three Rivers Park District (in person)
Philip Monson, MN Pollution Control Agency (online)
Susan Palchick, Hennepin County Public Health (in person)
Don Eaton, MN Dept. of Natural Resources (in person)
Vicky Sherry, US Fish and Wildlife Service (in person)
Christine Wicks, Chair, Minnesota Department of Agriculture (in person)
Jacob Bova, US EPA (online)

TAB Members unable to attend:
Steven Hogg, Three Rivers Park District
Chris Smith, MN Department of Transportation

All TAB Members received a draft report of the annual report to the TAB prior to the meeting.

MMCD Staff in Attendance

Daniel Huff, Mark Smith, Alex Carlson, Scott Larson, Carey LaMere, Kirk Johnson, Janet Jarnefeld, Jon Peterson, Nancy Read, John Walz

Guests

Allison Goldbeck (MDH), Alex Garvin (MDH), Jordan Mandli (MDH)

Welcome and Call to Order

Chair Christine Wicks called the meeting to order (in-person at MMCD office, and in virtual meeting room) at 12:30 PM, welcomed everyone to the meeting, and asked all present to introduce themselves, starting with new members. Dr. Jacob Bova is a Medical Entomologist who is replacing Don Baumgartner, and Don Eaton, an Aquatic Ecologist, has replaced Gary Montz from MnDNR. Steven Hogg, Wildlife Scientist, will be replacing John Moriarty, but could not be here today. Susan Palchick suggested that Amy Caron who works in epidemiology and environmental health at Hennepin County replace her next year.

Christine then called on MMCD staff for their presentations.

Recap of 2023 TAB meeting resolutions, Introduction of Daniel Huff, Executive Director – Mark Smith, MMCD Technical Services Manager

Last year at the meeting the TAB discussed their concerns about changing the statute to allow the Director to not be an Entomologist, and that was expressed in three of the resolutions presented. Chair Elizabeth Schiffman represented the concerns about having a science-based program to the Commission. The Commission's response included reaffirming the importance of science in directing the program, and establishing bylaws that require a certified entomologist on staff to advise the Director.

MMCD's new Executive Director, Dan Huff, introduced himself and described his background in Environmental Health, and how that field bridges between science and real-world applications. He appreciates learning from all the scientists on staff, and feels his work needs to be grounded in science. He takes the importance of public health seriously and is excited to be here and working with everyone.

In regard to the 4th TAB resolution about public input, Mark appreciates the suggestions received from TAB members and we will consider those if we move forward with this.

2023 Season - Overview
– Mark Smith, MMCD Technical Services Manager
Environmental conditions had a large effect on MMCD's work in 2023. After a dry previous year, we had unusually high snowfall plus early spring rain, leading to a lot of spring species larval hatch, and warm-up went quickly leading to the need to do large amounts of treatments in a short time. After that, dry conditions prevailed again and mosquito numbers dropped, but there was a need to focus on disease prevention.

The dry conditions limited our plans to expand services into outer areas, our ability to evaluate which sites will be productive, and our ability to test new materials. It also limited our ability to train new staff. It enabled us to do some projects with monetary savings and try out some new processes for sharing staff.

In our winter workgroups we are exploring how we can expand into P2 regions, build site history given dry conditions, evaluate control materials, expand drone use, rebuild educational outreach programs, use new technology, revitalize sustainability initiatives, and promote positive culture.

DE – what are you doing with drones? MS – we can conduct applications with them very well, better swath coverage especially later in the year vs ground backpack applications. It's also allowed us to cut material costs in some sites. SP – do you use for mapping? SL – photo drones, yes when there is new construction our certified drone operators can take new aerial photography for mapping. SP – I was thinking about it for looking at changes in vegetation given the dry conditions. SL – That would be good to collect info on changes before the larger aerial photography is available. JM – we have started using drones for herbicide treatments and seeding in wetlands, cheaper than helicopters. SL – we have a larger drone now, upgraded COA, easier to do larger treatments.

Entomology Lab Update
– Scott Larson, MMCD Assistant Entomologist
Our surveillance program is based on both larval and adult surveillance. All larval samples are brought to the lab for identification and determination of whether they are human-biters. Since 2020 we had fewer larval submissions, originally due to COVID reductions in staff, now due to drought. We have set thresholds for species or species groups for decisions on larviciding. We also do adult surveillance, including a network of CO_2 traps, some of which are used for virus testing. Results for 2023 show the record high numbers of spring species, and remarkably low numbers for summer and cattail mosquitoes, both affected by the dry conditions. Scott showed maps summarizing the locations of where the different species groups were found, and pointed

out the difference in numbers between the core P1 area and outer P2 area where few treatments are made. The cattail mosquito prediction model was pretty accurate at anticipating the low numbers of cattail mosquitoes. He described some surprises from this year, such as the *Ae. cinereus* being more abundant than the *Ae. vexans*, and the increasing numbers of *An. quadrimaculatus*.
SP – the type local for *An. quadrimaculatus* is in MN, despite being more abundant in the south. Where does *cinereus* breed? SL – more likely to be small wetland pockets (vs. *vexans*). *An. quadrimaculatus* can be malaria vector. DH - habitat? – CL permanent water. SL – we found more *Ae. dorsalis*, brackish irrigation water mosquito, found more widely this year than usual.

Scott continued describing some new technology the lab is testing, including a new training microscope that's also useful for high-quality photos. We tried to test a couple of Biogents traps including a counter trap (automated counts with remote reporting) and some new CO_2 traps, but lack of adult mosquitoes made it difficult.

Predictions for 2024 – low numbers of cattail mosquitoes. There are so many spring *Aedes* eggs, expecting high numbers again. May be low numbers of summer mosquitoes again unless some very high rainfalls.
SP – is snowpack usually protective for *Ae. vexans* eggs? NR – could help with temperature and less chance of desiccation.

Mosquito-borne Disease Review
– Kirk Johnson, MMCD Vector Ecologist
Kirk Johnson presented an update on mosquito-borne diseases in the District, including impacts from the drought.

La Crosse encephalitis (LAC) is generally a preventable disease if human-generated trash habitat is reduced. We try to reduce this kind of larval habitat, and use adult monitoring to help find areas to focus on habitat elimination. We only used adulticides to reduce these mosquitoes 22 times last year. Lack of rain affected this species as well, after the wet spring, with lower levels most of the year. There were 31 LAC cases in the US, of which one was in MN, and we responded by checking area to reduce habitat and existing populations. During previous drought periods we had also seen reduced vector numbers and reduced cases, but the virus is still active. Many exposures can lead to asymptomatic infections.

Jamestown Canyon virus (JCV) is related to LAC. Two cases were reported in 2023 although exposure sites are not definitive, Anoka County and Ramsey County could be involved, in areas where there were a lot of spring mosquitoes. Cases are more common in wooded areas in northern MN, and most District residents who have been diagnosed with JCV have had significant exposure opportunities outside the District. We have been testing mosquitoes from northern Anoka and Washington counties and have found seven positive for JCV of 877 submitted. *Ae. provocans* has been the most common species positive, but other species are suspected as well.

EEE was lower nationwide this year, with none in MN. There were extremely low populations of the vector, *Cs. melanura*, consistent with very dry conditions in the bogs where they develop.

For WNV nationwide there was a lot of activity in Colorado. In Minnesota there were 43 WNV cases in Minnesota with three fatalities. *Culex tarsalis* numbers were extremely low in 2023 due to drought. However, *Cx. restuans* and *Cx*. *pipiens* numbers were fairly abundant and early given the warm weather, as they use stormwater sites that hold water during dry periods. The WNV infection rate in the mosquito pools was fairly high, and given the dates of onset of disease cases, that suggests that *Cx. pipiens* may be involved.

DH – are all of these reportable diseases? ES – yes. For EEE there have been equine and wildlife cases reported but not human. DH – any locally-acquired malaria? ES – not in modern times. KJ – prior to 1920s were found. SP – demographics on WNV cases? MDH can look up. DE – do you have problems getting access to private property for tire etc. removal? KJ – we have access, rarely have had issues but has increased somewhat in recent years since Covid, sometimes it takes some discussion with landowner. We do have statutory authority but rarely have to call in other enforcement agencies.

MMCD Black Fly Control Program
– Carey LaMere, MMCD, Black Fly Specialist
Carey gave a quick overview of the black fly program. Surveillance was initiated in 1984, and large river treatments began in 1990. We do both adult and larval sampling. For small streams we have a threshold of 100 per grab sample. We recently added another species (*Simulium tuberosum*) for spring treatments based on reports of human impacts. This is a multivoltine species so we can treat it more than once. Large river sampling is performed using plastic tape samplers at 31 sites. Adult monitoring has 54 sweep locations and 13 CO_2 locations. Black flies from the Monday night network are useful for general numbers but cannot be identified.

We continued the nontarget impact monitoring which is in place to detect any changes in the macroinvertebrate community. This work had to be cancelled in 2021 due to low water levels but samplers were put out in 2022 and we are analyzing those results now.

Treatments this year in spring were more common than usual, with 88 treatments done and more gallons of material needed. In summer there were less treatments needed, and many times we had to remove samplers because of low flow.

Adult numbers reflect the dryness, except for one peak after we stopped treatments. Annoyance complaints were higher in the spring but were less than in the first years of *S. tuberosum*.

TAB members and MMCD staff thanked John Walz, retiring Black Fly Specialist, for his many years of work in the Black Fly program.

Ten-minute break

Recognition of Service
Dan Huff and Mark Smith presented tokens of appreciation to retiring TAB members Susan Palchick and John Moriarty and thanked them for their years of service on the Board. Mark acknowledged Donald Baumgartner's resignation from the board and will send a plaque to show our appreciation for his 12-years of service.

Data Systems, Wiki, and Analytics
- Nancy Read, MMCD, Data Systems Coordinator
MMCD's data systems are designed to both meet record-keeping requirements and provide information for planning and large-scale decision-making. Nancy reported on an upgrade of the web-based data system used for data entry and reporting, plus the addition of an internal wiki for knowledge management and access for all staff. We are also developing new tools for data analytics to help evaluate changes over time, and she demonstrated an interactive graph for exploring adult mosquito count data for the last 10 years.

CW – appreciate the PR work done this spring when the mosquito counts were so high.

MMCD Tick Vector Services and Tick Surveillance
– Janet Jarnefeld, MMCD, Tick Specialist
Janet Jarnefeld presented data on MMCD's tick work. MMCD conducts tick surveillance because of a legislative mandate in 1989, and we have been in communication with MDH on the possibility of physical tick control as directed in the mandate.
In 2023 field work for the long-term monitoring study was transferred back from field offices to tick program staff, so Janet spent a lot of time in the field. The average *I. scapularis* per mammal was 1.03, lower than the record high last year. Several other additional projects were done. We responded to a request by Jordan Mandli from MDH asking for ticks for tularemia testing. We supported testing by U of M researchers on Powassan virus by providing cardiac punctures and additional ticks from routes. Tick dragging was done at a series of parks. Results showed ticks in all seven counties, nymphs plus adults. Both *Dermacenter* and *Amblyoma* were collected. We have not found any *H. longicornis* in MN yet.

We will expand tick drags in 2024, and CDC will test ticks. We also will expand Powassan virus detection work.

Technology Update
– Mark Smith, MMCD Technical Services Manager
Mark discussed some new technology MMCD is using.

- The drone program is expanding for treatments, including a larger drone. We shifted to DJI Agras drones, which have better safety features. Drones provide better coverage and are safer for employees than walking through sites and can reduce cost per acre.
- BG Counter traps are being used in some other parts of the country with remote data collection.
- Data systems upgrade is underway as Nancy described, developed with the Computer Support team, uses input from users. Good to get more ways to analyze the data as well.
- Automated identification is a coming trend, we are planning to assist by providing samples to help train the systems. For now, these systems are slower than our lab staff.
- Looking at Lidar from drones as a possibility for additional mapping. High resolution lidar images may be useful for identifying what are the most productive areas of the sites, assist in directing staff, and cut out treatment application where not needed. There will also be lidar available from other government sources.

We continue to innovate to improve our operations, and encourage our staff to network with other mosquito control agencies, and exchange ideas.

New Use Patterns & IPM Plans
– Mark Smith, MMCD Technical Services Manager
Last year we tried a different use pattern, applying prehatch materials in mid-August for control of floodwater mosquitoes given our declining numbers of staff at that time of year, and the need for concentrating on cattail mosquito surveillance. This was useful when a rainfall occurred in late August and many sites were already treated.

MMCD is reviewing new ways to expand treatments into P2 areas, and looking at our control material budget. Traditionally we have reserved budget for summer needs, and may have held back earlier in the year. If not used, those funds go into a reserve. We are looking at ways to optimize that use.

In the spring, we are considering doing more prehatch treatments so we don't have to go back and inspect a site multiple times. We do a lot of response to rain events, but how can we make good use of the time in between those events? Would like to make sure that we use IPM principles and justify prehatch treatments, but may be difficult when there has been dry conditions inhibiting sampling. Would like to be able to do check and treat, but hard to do that and cover the expansive area needed. Also looking at some shorter duration prehatch materials, some are available for 7-day control (Censor – spinosad) instead of 30-day. Looking for ways to possibly do tasks differently.

SP – re prehatch and spring *Aedes*, historically we are pretty good at characterizing a *vexans* site, are we confident about spring *Aedes* sites? JP – have pretty good confidence for springs, big questions is timing. KJ – many species with different timing, different water temp preferences, but staff know sites, issue in part was fast warm up. JP – people know it's pretty dry, don't want to waste material, but want to be able to do something. The dipping is harder, not as abundant. SL – may be in not only vernal pools, also ditches, other habitats. MS – trying to keep track of weather conditions and what that implies. May wait and not apply a 30-day material until we know there is a good chance the sites will be wet. KJ – a big challenge has been staffing levels for spring and fall due to state restrictions on number of days we can keep seasonal staff. SK – finding that HR making decisions on traditional model, may want to try for a letter of waiver. JM – we run into the 180-day limit as well, costs a lot more after that length. JM – if you hold off on treatment until it rains, do you have enough helicopter time? MS - can get 6 to 7 helicopters.

SK – have you considered doing resampling on data to see if you can use it for prediction? We have tried that for building sampling, has been eye-opening for being able to predict from smaller sample size. Not only from rainfall and temperature, maybe look also at what land is like. Could resample 1000s of times and see how predictive it is, evaluate scenarios. Could be useful. NR – have done some work on that front but would like to know more about those techniques.

Mark conveyed that the Commission was open to having TAB members visit, and good for TAB to know what Commission is dealing with. Hoping to expand ways to have interaction.
CW will not be available Apr 24 for presentation from TAB to Commission, but if some other TAB member could attend that would be great, otherwise Mark will cover.

Discussion and Resolutions
– Chair Christine Wicks, MDA
The Chair asked if there were resolutions that the Board would like to make.

Board members chose to start with one similar to previous, expressing their overall support.

Resolution #1 The TAB supports the program presented in the 2023 review and acknowledges and appreciates the efforts of the MMCD staff in its preparation.

Made by JM, Second by ES.

No discussion. Motion approved without dissent.

Resolution #2 The TAB supports the innovations and technological advancements used in the delivery of services for the residents of the District

Made by JM, second by SP

Motion approved without dissent.

General discussion continued.

SK - Would TAB support be helpful for directing monetary support for research and analysis as needed? DH - doing ok on that so far. SK – other needs? JP – doing ok, evaluating what we need.

MS – are there things we can provide to the TAB to help keep you connected? JM – demos in the field would be great. CW – Dept of Ag visited when MMCD was calibrating drones, very useful. Other opportunities like that would be great. SK – has been working with Alex and Mark on videos for a class, very helpful. Worked with Kirk on workshops for pesticide applicators. AC – doing an outdoor field day as part of our pesticide applicator renewal, July 18 (category L). Mark can send out info as needed.

CW – reminded all that report includes many proposed activities for 2024, check that out.

Discussion re Resolution #3:

CW – question on concerns re malaria and *Anopheles quadrimaculatus*? Also *Cx. pipiens* and WNV, are these something that would be worth including in a resolution? DH - perhaps acknowledge climate change and influence on vector-borne disease, TAB supports continued emphasis on monitoring and addressing new challenges. DE – do you also mention dengue, more prevalent in southern US.

Resolution #3 The TAB supports MMCD's continued emphasis on surveillance of disease vector species and acknowledges influence of climate change and the need for monitoring and addressing new and emerging vector-borne diseases

Made by CW, second by ES

Motion approved without dissent.

Discussion – ES – importance of detecting and planning for new and emerging issues, both mosquitoes and ticks

CW – do we want to call out concerns re malaria vectors? ES – humans are the reservoir for malaria, not as much an issue in MN right now

Closing
The Chair called for a vote on adjournment and the meeting adjourned at 3:50 PM.
Motion by SK, second by JM. Approved.

Our Mission

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

Our Vision

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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