METROPOLITAN MOSQUITO CONTROL DISTRICT
2021 OPERATIONAL REVIEW & PLANS FOR 2022

Annual Report to the Technical Advisory Board

Staff from the Maple Grove facility and "Vectoria," the MMCD mosquito mascot at a parade in 2021. MMCD photo

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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 2022

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Mandy Meisner	Anoka County
Robyn West	Anoka County
Gayle Degler	Carver County
Tom Workman	Carver County
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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 2021-2022

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Janet Jarnefeld	Technical Services/Tick
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Nancy Read	Data Systems Coordinator
Mark Smith	Technical Services Coordinator
John Walz	Technical Services/Black Fly

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APPENDICES

Executive Summary

The Metropolitan Mosquito Control District (MMCD or the District) strives to provide cost effective service in an environmentally sound manner. This report presents MMCD efforts to accomplish that goal during 2021 through mosquito, black fly, and tick surveillance, disease monitoring, mosquito and black fly control, new product testing, data management, and dissemination of information to the public. It also presents plans for 2022 as we continue to provide an integrated mosquito management program for the benefit of metro area residents.

Mosquito Surveillance

The summer of 2021 was uncharacteristically hot and dry which impacted the timing and emergence of mosquito populations. The snowfall total from the preceding winter was 40.4 inches, 13.6 inches below normal, which set the stage for the drought conditions. Throughout the summer, temperatures were above average, and the seven-county metro was in severe or moderate drought from mid-June through August.

Adult spring *Aedes* emerged May 17 and peaked May 25. Our usual main pest mosquitoes, summer *Aedes,* peaked on June 8, which was much earlier than normal, after which the populations declined and remained low for the rest of the summer. 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 lower than normal and lower than expected based on previous history. The extremely low water levels in fall of 2021 reduced larval habitat for this species, and we expect adult populations to be even lower next year.

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.

After no reported human cases of WNV in 2020, the Minnesota Department of Health reported 27 WNV cases in 2021 with 22 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. There were six cases of JCV in Minnesota, with four cases occurring in District residents. Eastern equine encephalitis is a growing concern in Minnesota. There was one confirmed case in a horse in Itasca County in 2021. Thankfully, there were no human cases of EEE in Minnesota.

The District continued monitoring the distribution of ticks in the metro area. The average number of *Ixodes scapularis* (deer ticks) per mammal was 0.718 which is similar to most of the last 20 years but lower than last year. In 2021, 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*.

No tick-borne disease case data is yet available for either 2020 or 2021. There were 915 reported Lyme disease and 408 human anaplasmosis cases in MN in 2019, both lower than in 2018.

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 much of the year, MMCD only applied larvicide to 150,299 acres, which is over 40,000 fewer acres than in 2020 (194,911 acres treated). A cumulative total of 284,774 catch basin treatments were made to control WNV vectors. In 2021, 3,913 fewer acres of adulticide treatments were made (2,537 acres) than in 2020 (6,450 acres) due to fewer mosquitoes during dry weather and maintaining only one staff member per vehicle protocol as a precaution against COVID-19 transmission.

We planned to reinstate about one third of the larval control cut in 2017 because the District's financial situation supported it. However, with dry conditions in 2021 this additional control was not needed. The District plans to reinstate 100% of larval control in 2022 if weather conditions require it.

To control black flies in the metro area, MMCD made 58 small stream treatments and 52 large river treatments with *Bti* when the larval population of the target species met the treatment threshold. The average number of adult black flies per sweep in 2021 was 0.18, which is much lower than the 1996-2020 average of 1.28. This was the first year that *Simulium tuberosum* larval populations were treated in small streams, responding to public concern from high populations of this species in recent years. Due to 2021 drought conditions, scheduled non-target monitoring on the Mississippi River was postponed until 2022. In 2022, 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 2021, we verified that 5 lb/acre dosages of VectoBac® G *Bti* was sufficient to achieve good control of spring *Aedes* and *Ae. vexans* in sites treated by helicopter. This reduced rate (vs. 8 lb used previously) can help us get to more sites with the same amount of material.

We continued testing *Bacillus sphaericus* products that could provide an additional way to reduce WNV vectors in catch basins. VectoLex® FG granules (20 g/catch basin) effectively controlled mosquito larvae, verifying 2019 and 2020 results. The VectoLex® WSP water soluble pouch formulation (which does not require the applicator to wear an N95 mask) also provided good control at one and two pouches /catch basin. We may do further tests on VectoLex® WSP in 2022 to evaluate dose and application methods.

Data Management, Public Information, Sustainability, and New Technologies

MMCD continued to explore how drones can be incorporated into our program. MMCD expanded larvicide treatments by drone in regular operations, and in 2021 staff treated 132 sites using Altosid® P35 and VectoLex®. This was more than twice as many as the 63 sites treated in 2020. We also continued our use of drones for aerial photography and site scouting.

Technical and Field staff worked together to assemble information on our Integrated Pest Management Plans in a standard format to help all staff understand the basis for control efforts for our different pest groups, when and why they are needed, and how they can be conducted to provide public benefit and minimize nontarget impacts.

Public requests for adult mosquito treatments peaked in early June at the same time as the peak of mosquito numbers in sweep collections, but overall were down significantly from 2020. MMCD returned to several in-person events in 2021 including the Minnesota State Fair and several county fairs. Staff also supplemented our in-person public education with several new videos and increased website and social media activity.

Sustainability efforts continued to expand and become an integral part of MMCD operations, but due to the COVID-19 pandemic some activities remained scaled back in 2021. We continue to implement initiatives to reduce overall energy use and shift to renewable sources, reduce waste, and support our community through social responsibility initiatives.

Chapter 1 Mosquito Surveillance

2021 Highlights

- Snowfall season total was 40.4 inches, 13.6 inches below normal
- After two large rain events in May, dry conditions prevailed until mid-August
- The summer of 2021 was warm and dry. Temperatures were higher than normal, and the 7-county metro area was in severe or moderate drought for most of the summer
- There were two large summer floodwater broods & six small-medium broods
- Identified 12,923 larval and 7150 adult samples (excluding NJ trap samples)
- Adult spring *Aedes* emerged May 17 and peaked May 25
- The major summer *Aedes* emergence was June 8. This was the only large peak of the summer due to the dry conditions
- *Cq. perturbans* emerged beginning June 8 and levels were low through August
- Predicted catch rate for *Cq. perturbans* for 2021 was 47.3/trap. The actual value was 28.3/trap. The prediction for 2022 is 24.7 per trap
- Added long-term CO_2 trap locations to augment adult species information

2022 Plans

- Evaluate placement of CO_2 and gravid traps

Background

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

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

The District focuses on four major groups of human-biting mosquito species: spring *Aedes*, summer *Aedes, Coquillettidia perturbans,* and disease vectors. Snowmelt induces spring *Aedes* (15 species) eggs to hatch in March and April and adults emerge in late April to early May. These species have one generation each season; however, adults can live for three months and lay multiple egg batches. Summer *Aedes* (five species) begin hatching in early May in response to rainfall and warmer temperatures. Adults can lay multiple egg batches and live on average two weeks. *Coquillettidia perturbans* (the cattail mosquito) develops in cattail marshes. There is one emergence, which begins in early June, peaking around July 4. Disease vectors include *Aedes triseriatus*, *Culiseta melanura*, and *Culex pipiens*, *Cx. restuans*, *Cx. salinarius*, and *Cx. tarsalis* (*Culex*4 mosquitoes). Adults are evident in early summer, and they can produce multiple generations per year. Appendix A contains a species list and detailed descriptions of the mosquitoes occurring in the District.

2021 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 was 15.43 inches – well below the 62-year District average of 19.88 inches. April rainfall can influence adult emergence in May as well. The average precipitation for the weeks of March 28 through October 9, 2021 was 18.59 inches.

Figure 1.1 shows the sum of daily rainfall averages by week across the District from April–September 2021. Average weekly rainfall over the one-inch threshold occurred seven weeks from May through September. Heavy rains occurred the last two weeks of May. Rain events on May 20 and May 21 totaled 1.29 inches. The following week a large rain event occurred on May 28 (0.82 inches). It was relatively dry from June through early August when much of the District was in moderate or severe drought. There were rain events each day during week of August 23-29: averages of 0.81 inches on 8/24, 0.63 inches on 8/25, 1.74 inches on 8/27, and 0.91 inches on 8/29.

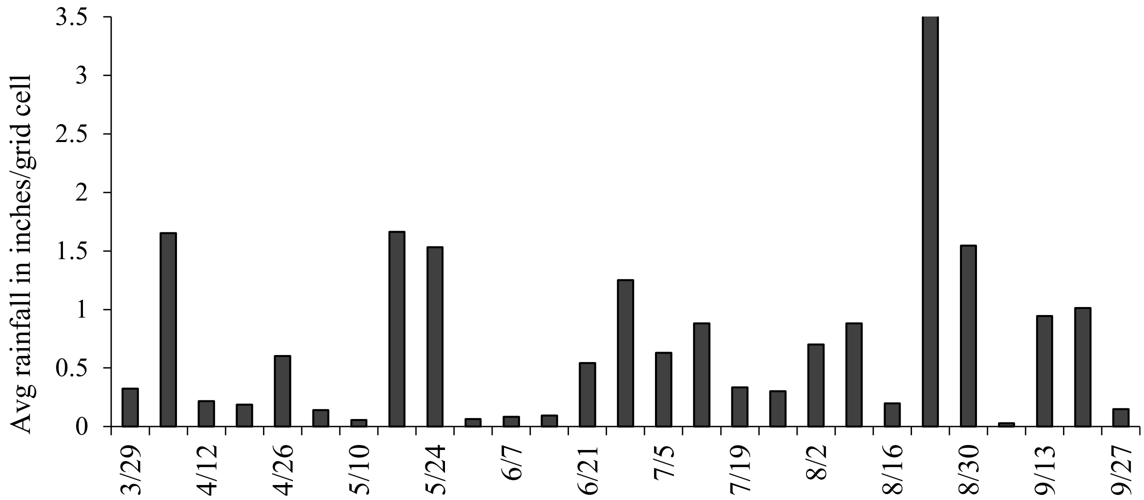


Figure 1.1 Sum of daily rainfall averages per week per grid cell, 2021 (RFC data). Dates represent the Monday of each week.

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 2020-2021 was a temperature roller coaster. Temperatures in January and March were both over 6.5- and 7.0°F above normal, respectively. February, in contrast, was 9.1°F below normal. An arctic cold snap began on February 6 and lasted until February 20. Extreme cold took hold on February 11 when temperatures did not break 0°F until Feb 16 (4 pm). April and May were much closer to normal. The frost left the ground on March 21, and ice-out on Lake Minnetonka occurred March 30; the average ice-out date is April 13.

The snowfall total for the season was 40.4 inches from November-March. The Twin Cities normal average snowfall is 54 inches (from 1981-2010). Precipitation was near normal from January through April (Fig. 1.2), was below normal in May, much below in June and July, and even though we had above average rain in August, it was not enough to raise the water level of many sites and did not result in large broods. Summer was warm and dry and much of the District was in moderate to severe drought for most of it.

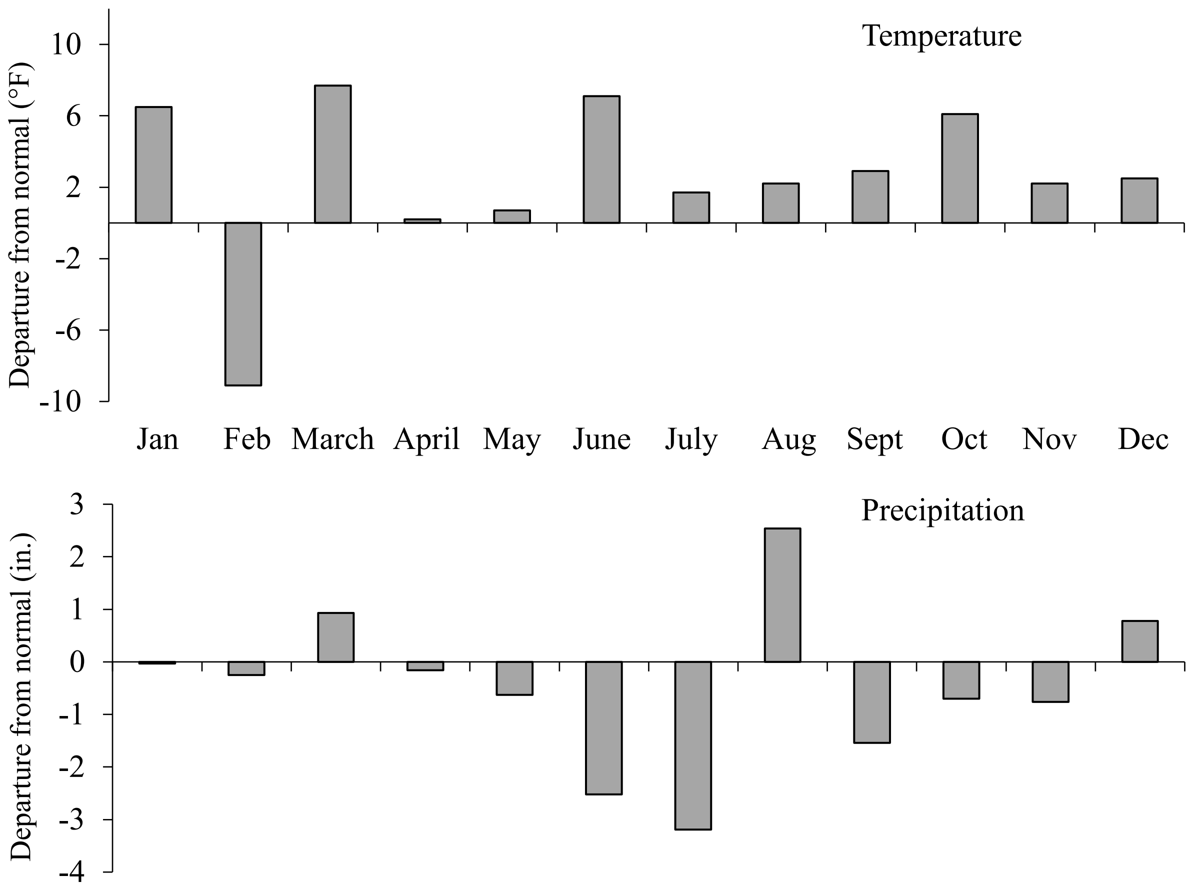


Figure 1.2 Monthly departures from normal for temperature and precipitation January–December 2021 (source: National Weather Service, Twin Cities Station).

Snowmelt and rainfall during March through early May triggered spring *Aedes* and floodwater *Aedes* to hatch. By May 5, the species composition transitioned to floodwater *Aedes*. There were eight rain events sufficient to produce floodwater *Aedes* hatches (i.e., broods): two were large, District-wide events (May 22-26 and August 27-September 2), and six were small to medium rain events that occurred in localized areas of the District. 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 April – September 2021. 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.

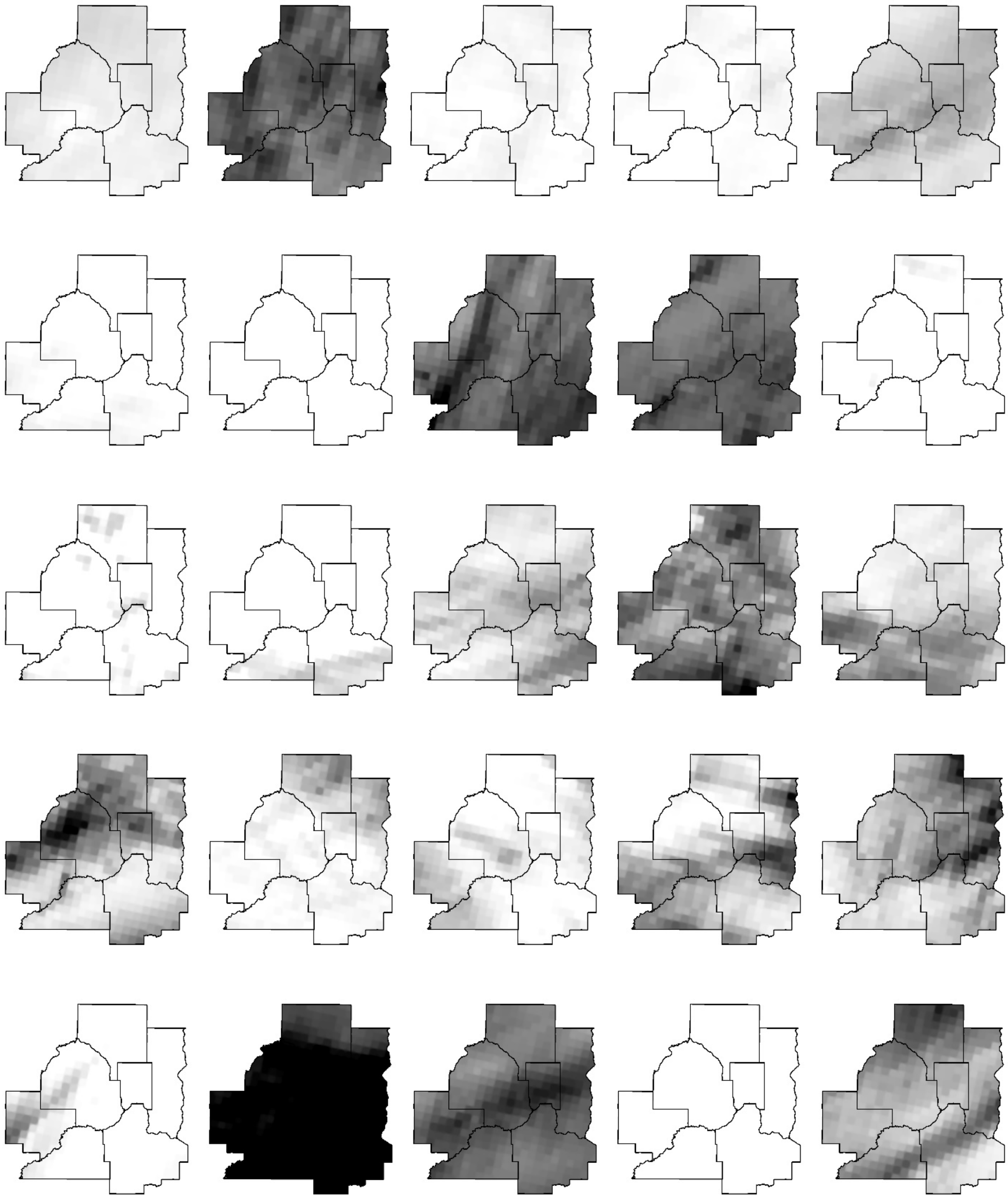
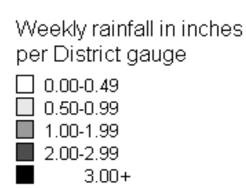


Figure 1.3 Weekly rainfall in inches, 2021. RFC-corrected data using 406 4x4 km grid cells. Inverse distance weighting was the algorithm used for shading of maps.



Larval Collections

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

To expedite sample processing for high priority helicopter treatments (air sites), most larvae are identified to genus only, but again in 2021 we identified the spring *Aedes* to species until May 5, 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 2021, lab staff identified 12,923 larval samples (Fig. 1.4). The 25-year average is 19,957 larval samples per year. The low number of samples in 2020 and 2021 was related to decreased staffing levels due to the COVID-19 pandemic.

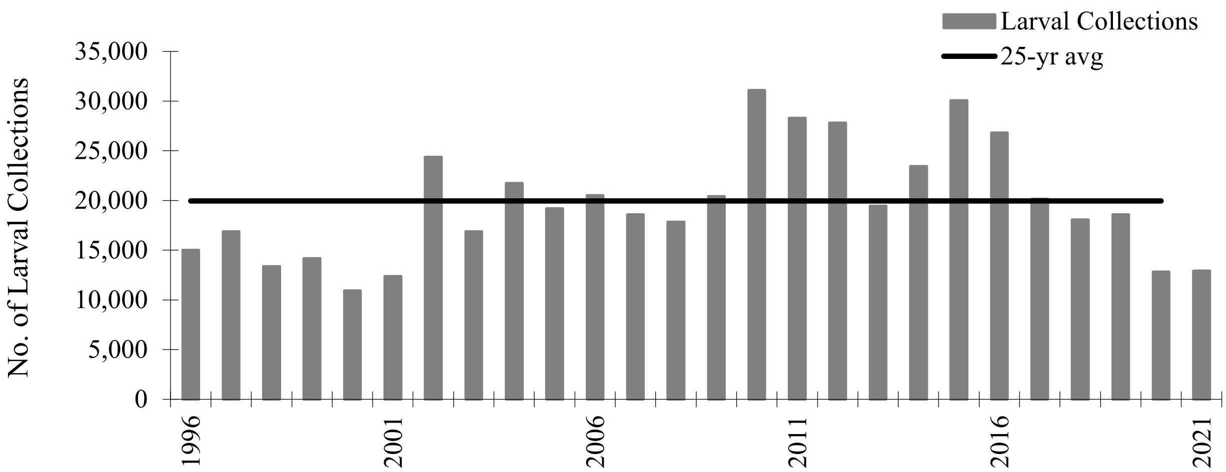


Figure 1.4 Yearly total larval collections, 1996-2021, and 25-year average. Prior to 2015, these totals did not include container samples.

The results of 10,835 samples identified to species, calculated as the percent of samples in which the species was present, is shown in Table 1.1. Most larval sampling takes place in natural wetlands, but a significant amount of sampling is done in catch basins, stormwater structures, and other man-made features (e.g., swimming pools, culverts, and artificial ponds). Those results are displayed separately (shaded column) from the natural wetlands results in Table 1.1. *Culex* mosquitoes are by far the most common species found in man-made features (structures).

Aedes vexans was the most commonly encountered species in wetland habitats (29.8% of total) followed by *Ae. cinereus* (21.6%), *Ae. excrucians* (15.0%), and *Cx. territans* (12.7%). *Culiseta inornata* was ranked 5th (11.3%) and *Cx. restuans* was 6th (10.1%). Again in 2021, species level identifications were done for air site samples to identify spring *Aedes*, which led to increased percentages of occurrence of some spring *Aedes* species from years past (Table 1.1).

Table 1.1 Percent of samples where larval species occurred in wetland collections by facility and District total, and the District total for stormwater structure samples, 2021; the total number of samples processed to species is in parentheses

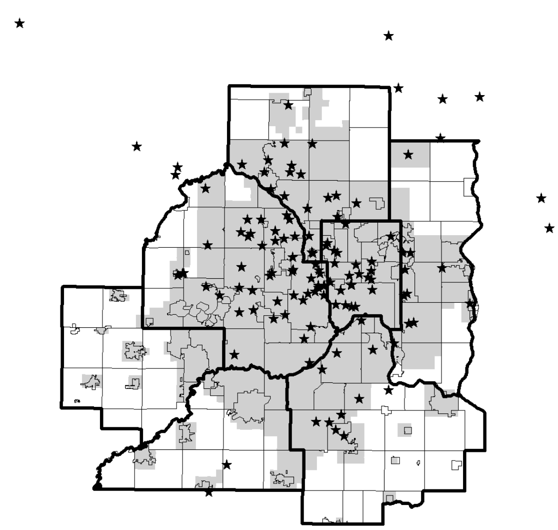
	Percent of samples where species occurred by facility							
Species	North (2,004)	East (2,376)	South Rosemount (910)	South Jordan (1,323)	West Plymouth (1,327)	West Maple Grove (797)	Wetland Total (8,737)	Structures Total (2,098)
Aedes abserratus	13.77	4.97	0.66	1.59	5.58	3.01	5.94	-
aurifer	0.45	0.25	0.11	0.15	0.08	-	0.22	-
canadensis	1.10	2.31	8.90	4.54	1.58	1.51	2.87	-
cinereus	26.90	15.28	9.67	22.98	28.64	27.23	21.64	-
dorsalis	0.05	0.04	0.22	0.15	0.08	-	0.08	-
excrucians	30.74	12.79	4.62	9.15	9.12	12.80	14.95	-
fitchii	5.44	2.61	1.43	0.76	0.45	1.13	2.39	-
flavescens	-	-	-	-	-	-	-	-
hendersoni	-	-	-	-	-	-	-	-
implicatus	0.55	0.38	-	0.08	0.08	-	0.25	-
intrudens	0.05	0.04	-	-	-	-	0.02	-
japonicus	0.35	0.67	0.33	0.15	-	-	0.32	3.48
nigromaculis	-	0.04	-	-	-	-	0.01	-
provocans	2.25	1.22	0.11	-	0.23	0.13	0.90	-
punctor	6.89	2.36	0.44	0.91	4.67	1.25	3.23	-
riparius	2.50	1.39	1.10	0.76	1.88	1.63	1.61	-
spencerii	-	-	-	-	-	-	-	-
sticticus	0.45	0.72	0.11	0.53	0.08	0.13	0.41	-
stimulans	14.07	8.59	5.82	4.91	5.28	6.40	8.30	-
triseriatus	0.05	0.04	-	0.15	-	0.13	0.06	0.43
trivittatus	0.70	3.16	4.29	0.68	0.45	0.38	1.67	0.05
vexans	30.89	36.20	35.71	28.95	19.22	20.45	29.82	4.77
Ae. unidentifiable	39.97	23.91	38.46	30.01	46.57	43.04	35.22	5.00
Anopheles earlei	-	-	-	-	-	-	-	-
punctipennis	0.95	1.09	0.33	0.15	0.08	-	0.58	0.57
quadrimaculatus	3.44	3.07	0.44	1.21	1.13	0.63	2.08	0.91
walkeri	0.05	0.04	-	-	-	-	0.02	-
An. unidentifiable	5.14	4.84	1.65	1.89	1.13	0.50	3.17	2.43
Culex erraticus	-	-	-	0.08	-	-	0.01	-
pipiens	3.99	11.74	4.29	3.40	4.90	2.13	6.01	41.80
restuans	6.34	16.16	10.77	10.28	9.27	2.26	10.14	61.06
salinarius	-	0.04	0.11	0.08	0.15	0.13	0.07	-
tarsalis	1.25	3.03	1.21	2.80	2.64	0.88	2.14	2.24
territans	10.33	19.91	8.79	14.66	7.61	6.52	12.67	16.92
Cx. unidentifiable	3.14	7.49	5.05	6.65	5.43	1.63	5.26	54.58
Culiseta inornata	4.34	7.66	14.18	17.99	15.15	18.70	11.29	2.14
melanura	-	-	-	-	-	-	-	-
minnesotae	0.15	0.38	0.11	0.15	0.08	0.13	0.19	0.05
morsitans	-	0.25	-	-	-	-	0.07	-
Cs. unidentifiable	1.10	1.22	1.21	0.38	1.28	1.13	1.06	0.10
Or. signifera	-	-	-	0.08	-	-	0.01	-
Ps. ciliata	-	-	-	-	-	-	-	-
ferox	0.15	0.17	0.11	-	0.08	-	0.10	-
horrida	-	-	-	-	-	-	-	-
Ps. unidentifiable	0.05	0.42	0.88	0.23	-	-	0.25	0.05
Ur. sapphirina	2.10	2.23	0.33	0.68	0.38	-	1.28	0.43

Adult Mosquito Collections

The District uses a variety of surveillance strategies to collect adult mosquitoes which exploit different behaviors inherent to mosquitoes. Sweep nets are used to survey the mosquitoes attracted to a human host. We use carbon dioxide-baited (CO_2) traps with small lights to monitor host-seeking, phototactic (i.e., attracted to light) species. New Jersey (NJ) light traps monitor only phototactic mosquitoes. Large hand-held aspirators are used to capture mosquitoes resting in the understory of wooded areas in the daytime. Gravid traps use an 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 the invasive species *Ae. aegypti* and *Ae. albopictus* and are placed in areas at high risk for species introductions. Ovitraps are used to collect eggs of container-inhabiting vector species (i.e., *Ae. triseriatus, Ae. japonicus,* and *Ae. albopictus*). The information obtained from sampling is used to direct control activities and to monitor vector populations and disease activity. Mosquitoes that vector pathogens that cause disease are discussed in Chapter 2: Vector-borne Disease.

Monday Night Network The sweep net and CO_2 trap data reported here are weekly collections referred to as the 'Monday Night Network'. Staff make two-minute sweep net collections at a prescribed time at their homes on Monday evenings to monitor mosquito annoyance experienced by citizens. In addition, CO_2 traps are set up in natural areas such as parks or wood lots to monitor overall mosquito abundance. To achieve a District-wide distribution of CO_2 traps, some employees set traps in their yards as well. Figure 1.5 shows the sweep net and CO_2 trap locations and their uses [i.e., general monitoring, virus testing, and eastern equine encephalitis (EEE) vector monitoring]. Although a few locations are located beyond District boundaries, only data from locations within are included in the analysis. Sweep net collections and CO_2 traps were operated once weekly for 19 weeks, May 17–September 20.

Sweep Nets



CO_2 Traps

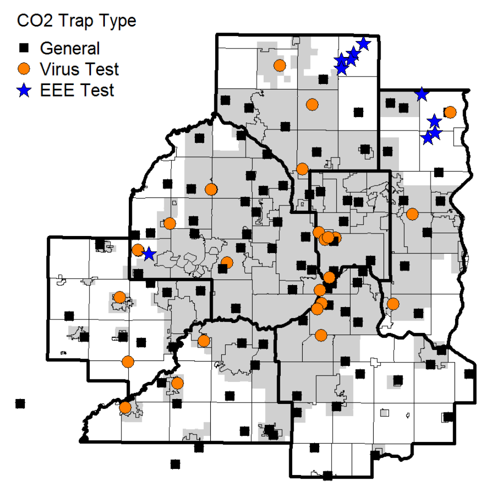


Figure 1.5 Locations of weekly sweep net and CO_2 traps used to monitor general mosquito populations and disease vectors (virus test and EEE test), 2021.

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 126 sweep locations in 2021 (up from 87 in 2020), and the number of collectors varied from 42-98 per evening. In 2021, the treatment threshold for sweep net sampling is two mosquitoes per two-minute sweep for *Aedes* and one mosquito per two-minute sweep for *Culex*4 and *Ae. japonicus*.

Staff made 1,438 collections containing 393 mosquitoes in 2021. Although sampling effort increased in 2021, there was a 67 percent decrease in the number of mosquitoes detected. The average number of summer *Aedes* collected in the evening sweep net collections in 2021 was the lowest in the past five years (Table 1.2). The number collected in 2021 decreased 75% compared to last year. Eighty-five percent fewer *Cq. perturbans* were detected in 2021 compared to last year as well. Levels of spring *Aedes* and *Cx. tarsalis* were typically low. Summer *Aedes*, *Cq. perturbans*, and spring *Aedes* were well below the 21-year average.

Table 1.2 Average number of mosquitoes collected per evening sweep net collection within the District, 2017-2021 and 21-year average, 2000-2020 (± 1 SE)

Year	Summer *Aedes*	*Cq. perturbans*	Spring *Aedes*	*Cx. tarsalis*
2017	0.79	0.49	0.01	0.001
2018	1.50	0.22	0.03	0.009
2019	0.55	0.14	0.09	0.003
2020	0.53	0.48	0.02	0.001
2021	0.13	0.07	0.01	0.002
21-yr Avg.	1.64 (±0.28)	0.33 (±0.05)	0.10 (±0.03)	0.007 (±0.001)

CO_2 Trap CO_2 traps baited with dry ice are used to monitor host-seeking mosquitoes and the presence and abundance of species that transmit pathogens that cause human disease. The standard placement for these traps is approximately five feet above the ground, the height at which *Aedes* mosquitoes typically fly. Some locations have elevated traps which are placed ~ 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 2021, we placed 138 traps at 126 locations (twelve of these locations have low traps paired with elevated traps) to allow maximum coverage of the District (Figure 1.5). An additional three traps were outside District boundaries, at employee homes, and were not included in these analyses. The "General" trap type locations are used to monitor non-vector mosquitoes. There are 44 traps designated as "Virus Test"; all *Culex*4 collected from these traps are tested for WNV (Figure 1.5). Additionally, *Cx. tarsalis* from all locations are tested. Eleven trap locations in the network have historically captured *Cs. melanura* and are used to monitor this vector species populations and to obtain specimens for EEE testing (Figure 1.5, "EEE Test" trap type).

A total of 2,255 District low CO_2 trap collections taken contained 164,075 mosquitoes in 2021. The total number of traps operated weekly varied from 116-121. The average number of mosquitoes detected in CO_2 traps is found in Table 1.3. Summer *Aedes* and *Cq. perturbans*, the two most abundant species, occurred at much lower levels than in the past five years. Summer *Aedes* populations (predominantly *Ae. vexans*) were very low in 2021 – an 81% decrease from 2020. Likewise, *Cq. perturbans* levels decreased from 2020 (down 78%). Captures of spring *Aedes* decreased as well. *Culex tarsalis* numbers, however, increased markedly; the increase from 2020 was 550% and levels were near the 21-year average. More in-depth discussion of *Cx. tarsalis* is found in Chapter 2: Mosquito-borne Disease.

Table 1.3 Average numbers of mosquitoes collected in CO_2 traps within the District, 2017-2021 and 21-year average, 2000-2020 (± 1 SE)

Year	Summer *Aedes*	*Cq. perturbans*	Spring *Aedes*	*Cx. tarsalis*
2017	134.8	140.8	2.5	0.6
2018	153.4	52.6	5.3	0.8
2019	160.1	66.1	6.5	0.7
2020	182.4	127.3	3.5	0.2
2021	35.0	28.3	2.7	1.3
21-yr Avg.	202.9 (±26.1)	57.0 (±7.8)	7.6 (±1.7)	1.7 (±0.3)

Geographic Distribution The weekly District geographic distributions of the three major groups of nuisance mosquitoes (i.e., spring *Aedes*, summer *Aedes*, and *Cq. perturbans*) collected in CO_2 traps are displayed in Figures 1.6, 1.7, and 1.8, respectively. The computer-assisted interpolations of mosquito abundance portray the predicted abundance of mosquitoes at locations without CO_2 traps. Therefore, some dark areas are the result of single collections without another trap in close proximity and may not reflect actual densities of mosquitoes. Priority area 1 (P1) receives full larval control. A full description of priority areas is in Chapter 4: Mosquito Control.

Spring *Aedes* populations were first detected May 17 in the northeastern part of the District (Figure 1.6). Highest levels were detected in northeastern Anoka County on May 24. The first detections of the summer *Aedes* occurred May 24 in northern Hennepin and Anoka counties (Fig. 1.7). The highest levels of the summer occurred June 7. Localized hotspots occurred each month around the District, but there were no widespread high levels through September. *Coquillettidia perturbans* was first detected in northwestern Washington County on June 1 (Figure 1.8). Emergence increased weekly thereafter. Highest levels occurred the week of June 28–July 5. Populations steadily declined thereafter. Highest levels occurred outside of P1 on the outer borders of the District. Results of sampling on June 21 may have been suppressed by low overnight temperatures; the temperature at 9:00 pm was 58°F and the overnight low was 53°F.

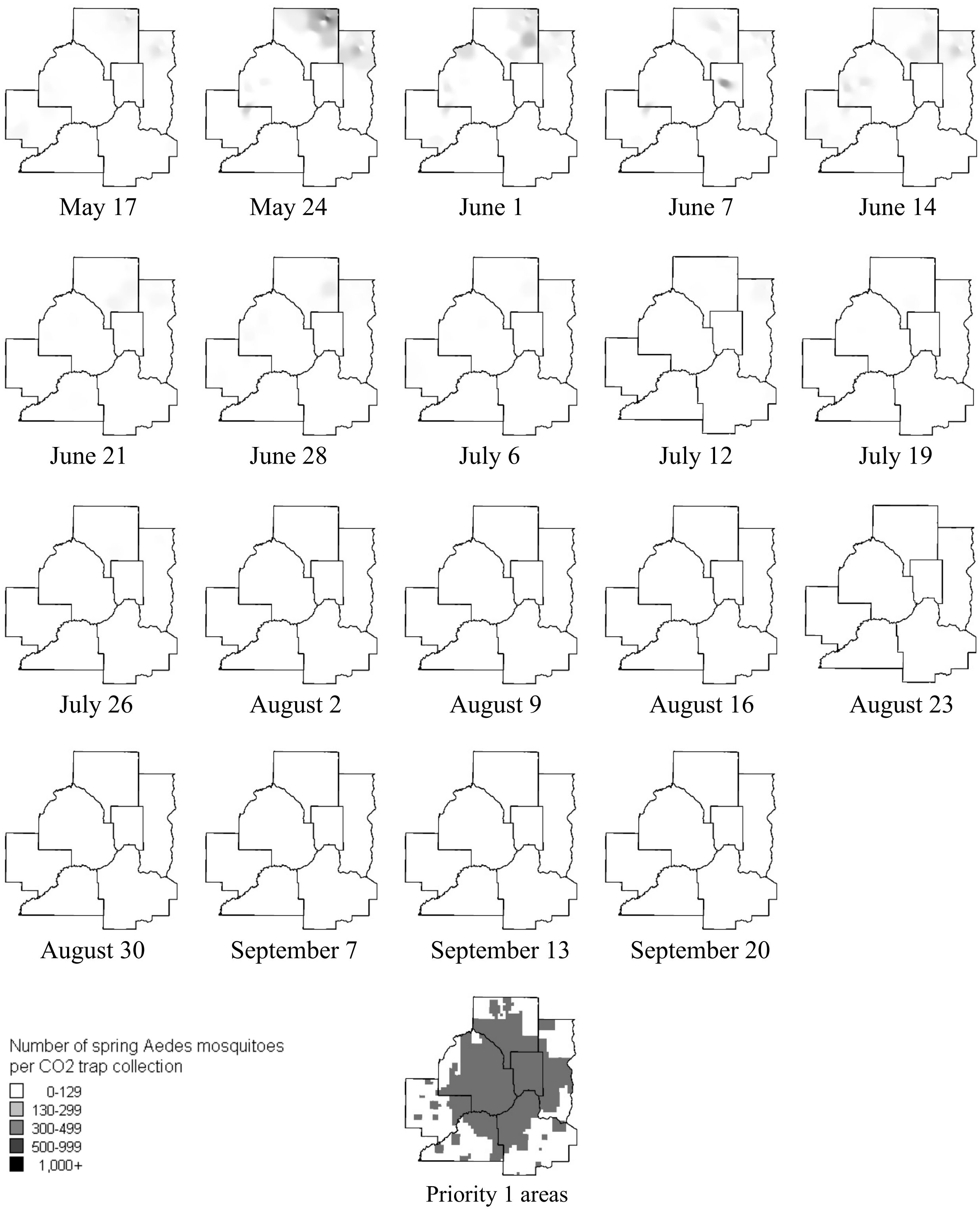


Figure 1.6 Number of spring *Aedes* in District low (5 ft) CO_2 trap collections, 2021. The number of traps operated per night varied from 116-121. Inverse distance weighting was the algorithm used for shading of maps. Treatment threshold is >130 mosquitoes/trap night. Priority 1 area map for reference.

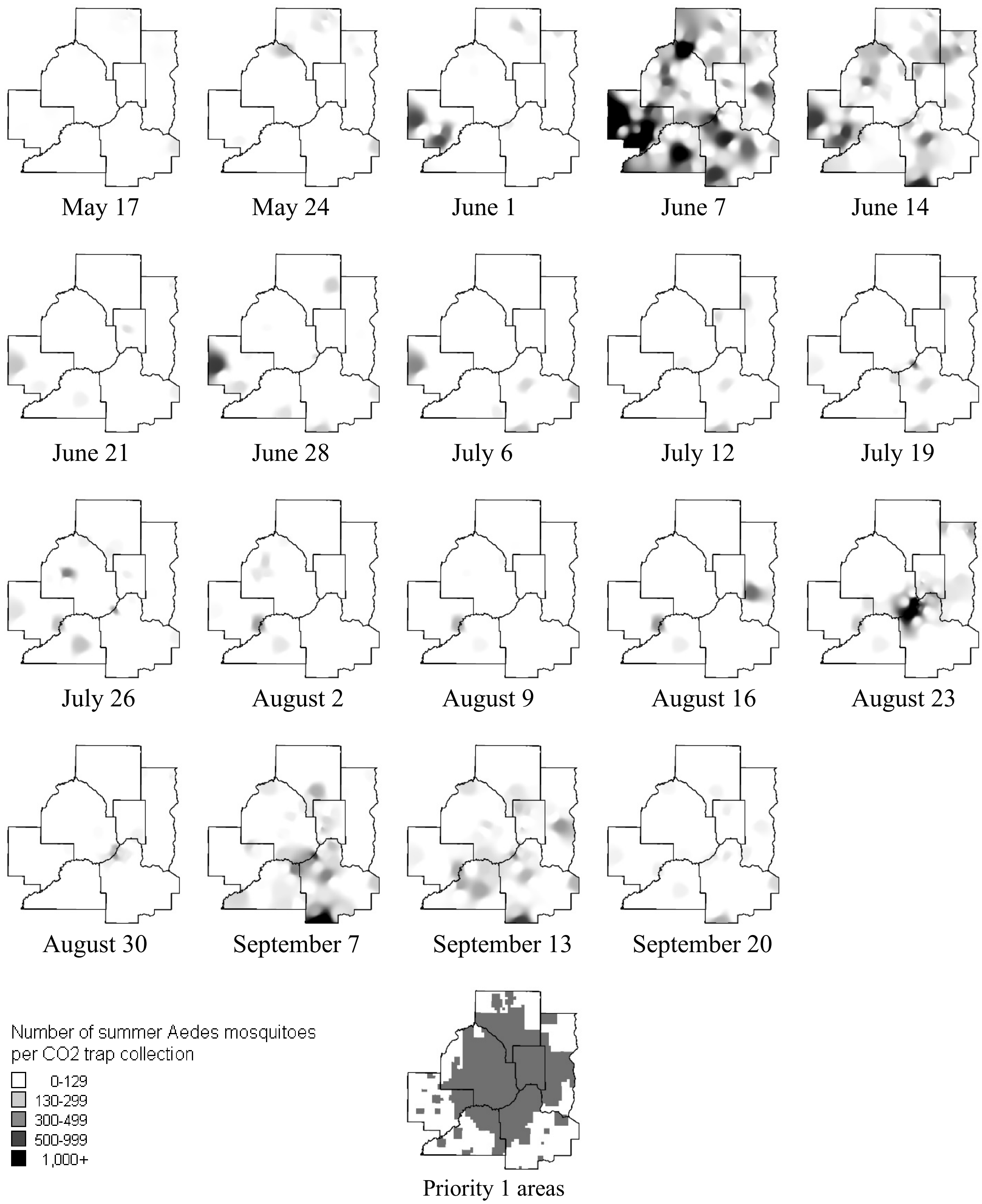


Figure 1.7 Number of summer *Aedes* in District low (5 ft) CO_2 trap collections, 2021. The number of traps operated per night varied from 116-121. Inverse distance weighting was the algorithm used for shading of maps. Treatment threshold is >130 mosquitoes/trap night. Priority 1 area map for reference.

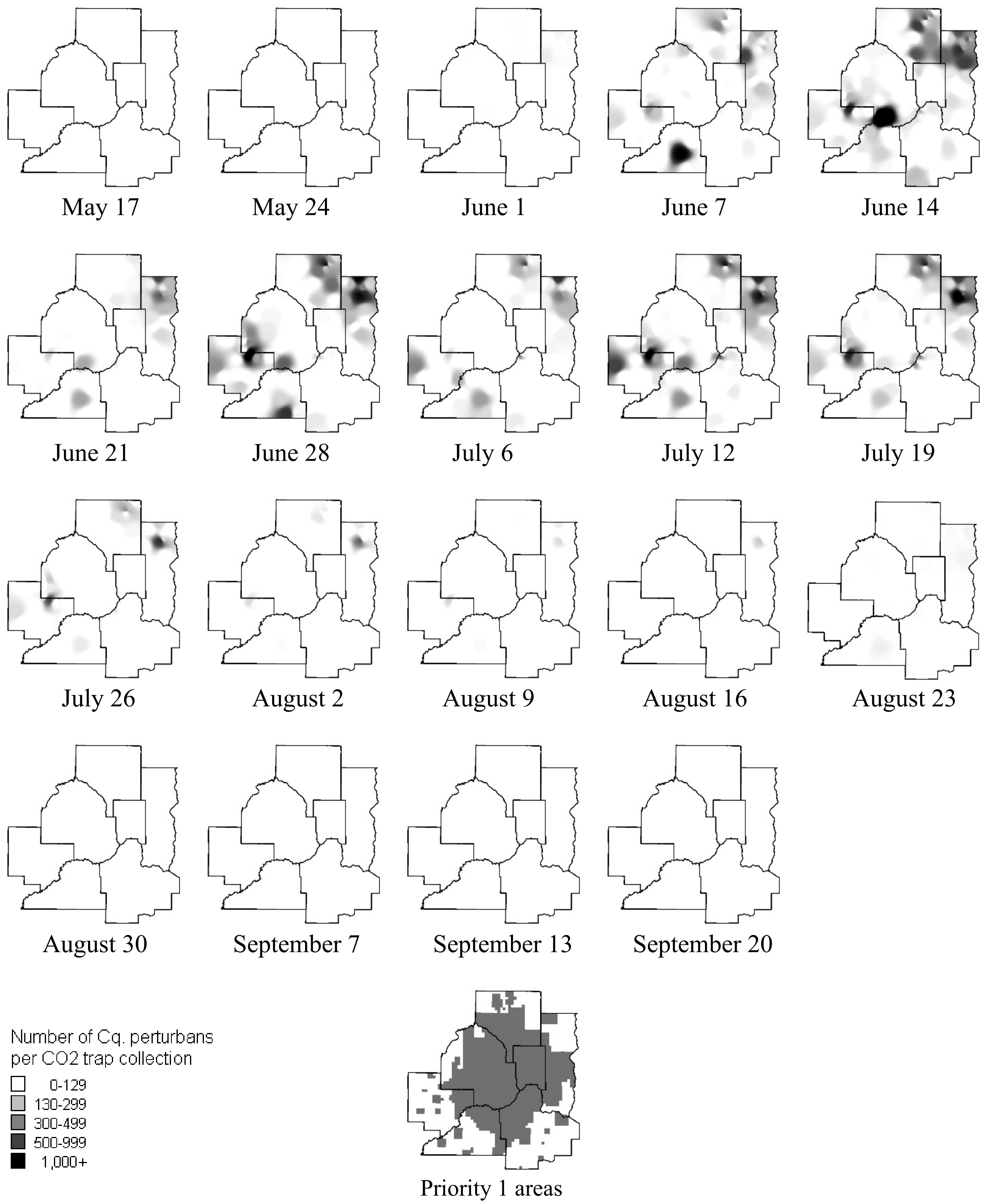


Figure 1.8 Number of *Cq. perturbans* in District low (5 ft) CO_2 trap collections, 2021. The number of traps operated per night varied from 116-121. Inverse distance weighting was the algorithm used for shading of maps. Treatment threshold is >130 mosquitoes/trap night. Priority 1 area map for reference.

Seasonal Distribution As described earlier, spring *Aedes*, summer *Aedes,* and *Cq. perturbans* have different patterns of occurrence during the season based on their phenology. Additionally, temperatures below 55°F inhibit mosquito flight activity. If rain or cold temperatures are forecasted on sampling night, surveillance is postponed until the next night. Figure 1.9 depicts the actual temperature at 9:00 p.m. on the scheduled sampling night. In 2021, sampling with CO_2 traps and sweep nets started May 17. Temperatures at the time of sampling were well above the minimum mosquito flight threshold, except for June 21 when the temperature was 58 degrees.

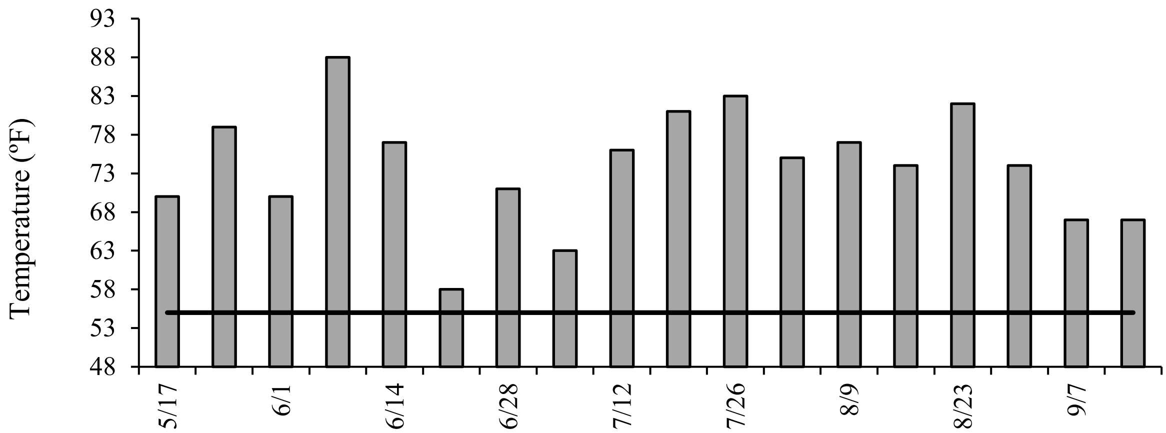


Figure 1.9 Temperature at 9:00 p.m. on actual dates of Monday night surveillance, 2021 (source: National Weather Service, Twin Cities Station). The black horizonal line indicates the mosquito flight threshold, 55°F.

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. Low levels of spring *Aedes* were detected on May 17, peaked on May 25 near the 21-year average, and declined thereafter and were well below the 21-year average (Fig. 1.10). Highest captures in CO_2 traps occurred on May 24, well-below the 21-year average (Fig. 1.11). Populations were detected in very low numbers though June.

Summer *Aedes* were first detected in sweep net samples on May 24 and in CO_2 traps on May 25 (Fig. 1.10 and Fig. 1.11, respectively). The summer *Aedes* in sweep samples were well below the 21-year average. CO_2 trapping detected summer *Aedes* the first sampling night and the highest levels were seen on June 8 (Fig 1.11). Very low levels occurred thereafter, and another small increase occurred August 24. Mosquito levels in CO_2 traps were well below the 21-year average throughout the summer.

The single generation *Cq. perturbans* was initially detected June 7 for sweep nets and June 8 for CO_2 traps. Sweep nets detected the peak on June 14 and the last *Cq. perturbans* was collected on August 9 (Fig. 1.10). The population was well below the 21-year average (Fig. 1.10). Highest levels in CO_2 traps occurred June 15, earlier than normal and at the 21-year average (Fig. 1.11). Populations were at levels beneath the 21-year average from June 21 through August 10 (Fig. 1.11) and after August 17 only a few specimens were collected each week to September 21.

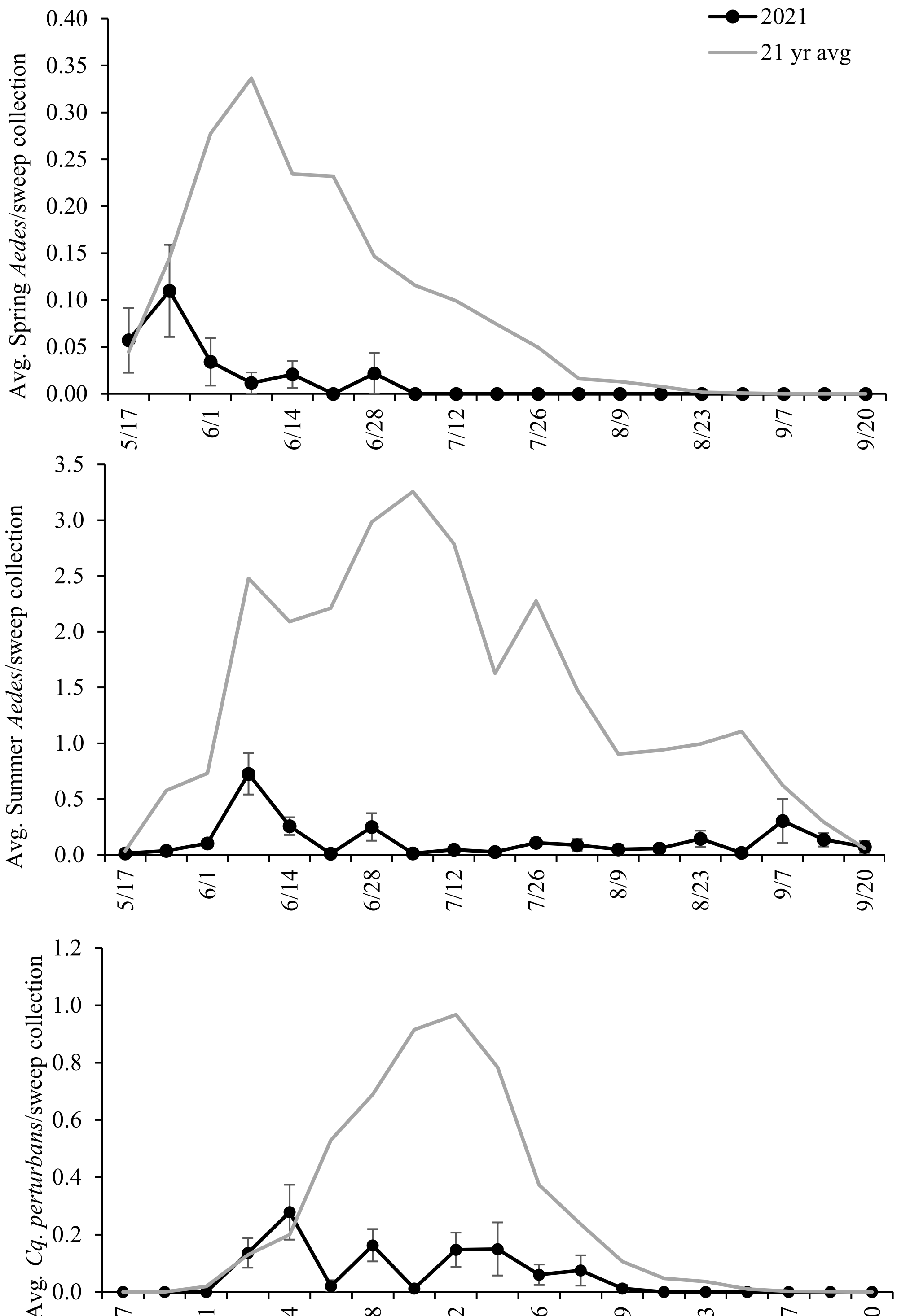


Figure 1.10 Average number of spring *Aedes*, summer *Aedes*, and *Cq. perturbans* per sweep net collection, 2021 vs. 21-year average. Dates are the Mondays of each week. Error bars equal ± 1 standard error of the mean.

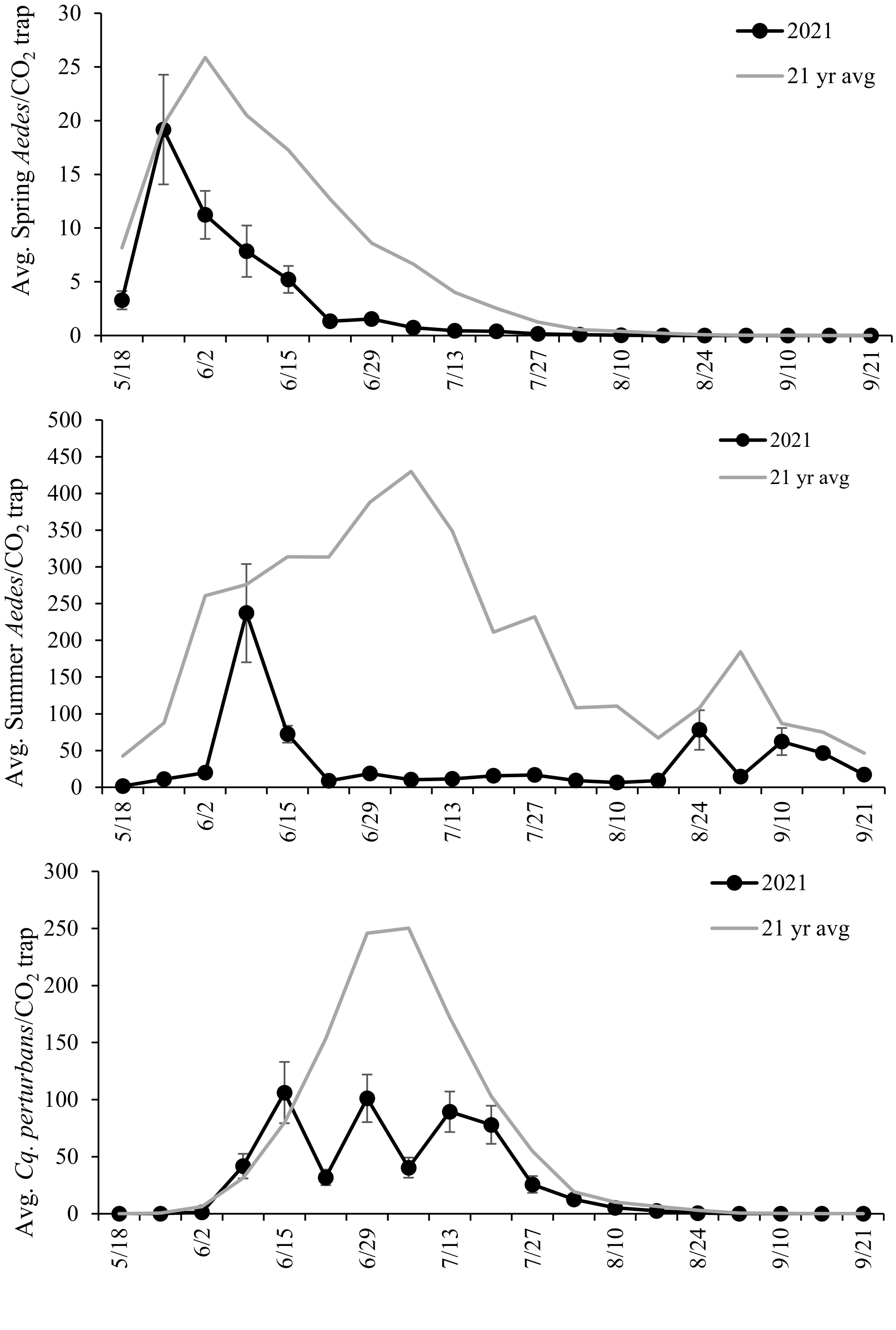


Figure 1.11 Average number of spring *Aedes*, summer *Aedes*, and *Cq. perturbans* per CO_2 trap, 2021 vs. 21-year average. Dates are the Tuesday of each week, except when sampling falls on a holiday. Error bars equal $\pm$ 1 standard error of the mean.

The difference in mosquito levels in priority zones (P1 = full larval treatment and P2 = no or limited larval treatment) is shown in Figure 1.12. Spring *Aedes* levels were low in both P1 and P2, and highest levels of summer *Aedes* were detected in P2. *Coquillettidia perturbans* levels were higher in P2 than in P1.

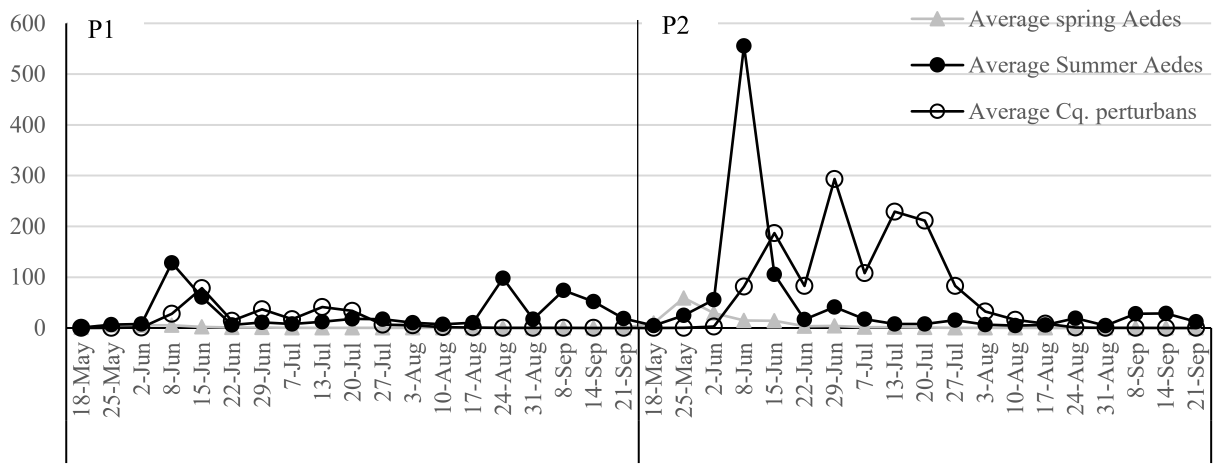


Figure 1.12 Average number of spring *Aedes*, summer *Aedes*, and *Cq. perturbans* per CO_2 trap, 2021 in P1 and P2.

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

In 2018, we reduced the trapping locations to only include those sites that were productive and that have been operating for twenty years or more. The four traps are in the following locations: Trap 9 in Lake Elmo, Trap 13 in Jordan, Trap 16 in Lino Lakes, and Trap CA1 in the Carlos Avery State Wildlife Management Area (Figure 1.13). Traps 9 and 16 have operated from 1965-2021. The CA1 trap started in 1991. Trap 13 has been at MMCD's Jordan Office location since 1998.

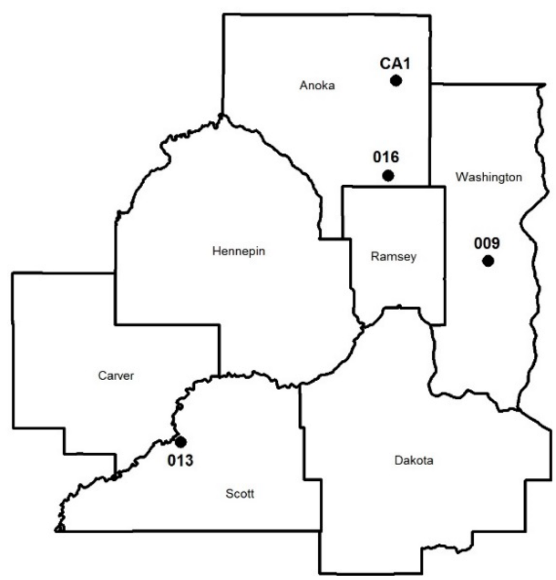


Figure 1.13 NJ light trap locations, 2021.

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. New Jersey trap identifications are not yet complete; a full analysis will be included in this final report. A comparison of the major species collected from those four traps is shown in Appendix B.

Start of Long-term CO_2 Trap Network

Until 2021, New Jersey light traps were the only adult surveillance method that was speciated. Because there are only four New Jersey trap locations, we wanted to augment the full adult species information from a wider geographic distribution in the District. We randomly selected 15 CO_2 trap locations from our Monday Night Surveillance network where we will do full species identifications. We divided the District into regions (S, W, NE), and randomly selected five traps per region. Selected traps were not at employees/past employee's homes and locations were at least 10 km (6.2 miles) apart. Figure 1.14 shows the selected traps from the Monday Night Surveillance network. Samples from these locations were initially identified to broad species group levels necessary for the Monday Night surveillance and then were saved for later full identifications. Full species identification has not been completed yet. Results will be in the final version of the TAB report.

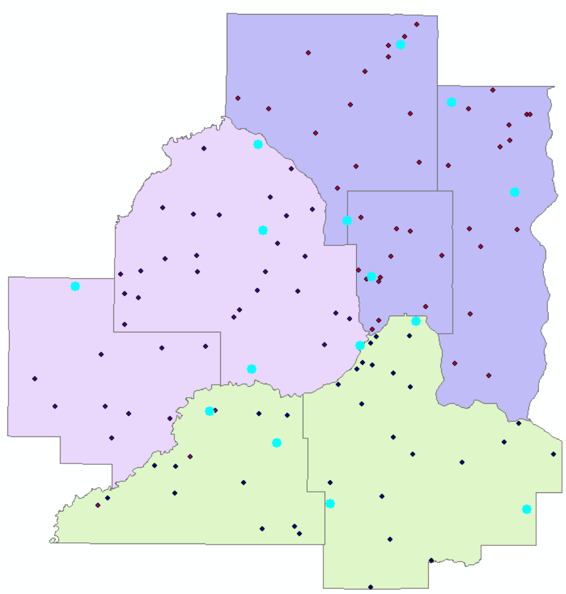


Figure 1.14 Locations of 15 traps selected for long-term CO_2 trap full species level identifications (aqua dots). Green shading is South, lavender shading is West, and purple shading is Northeast.

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, and adults emerge the following June-July, typically peaking around Independence Day. Adult populations are influenced by rainfall amounts from the previous year. Higher *Cq. perturbans* captures in CO_2 traps occurred (2003, 2011, 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 2021 was 47.3 *Cq. perturbans* per CO_2 trap, but the actual rate was 28.3 (Figure 1.15). The predicted number of *Cq. perturbans* collected per CO_2 trap in 2022 is 24.7. This model explains ~81% of the variation in predicted *Cq. perturbans* abundance (adjusted R-squared = 0.812). The prediction helps identify population trends for the coming year, and larval dips confirm abundance and treatment locations.

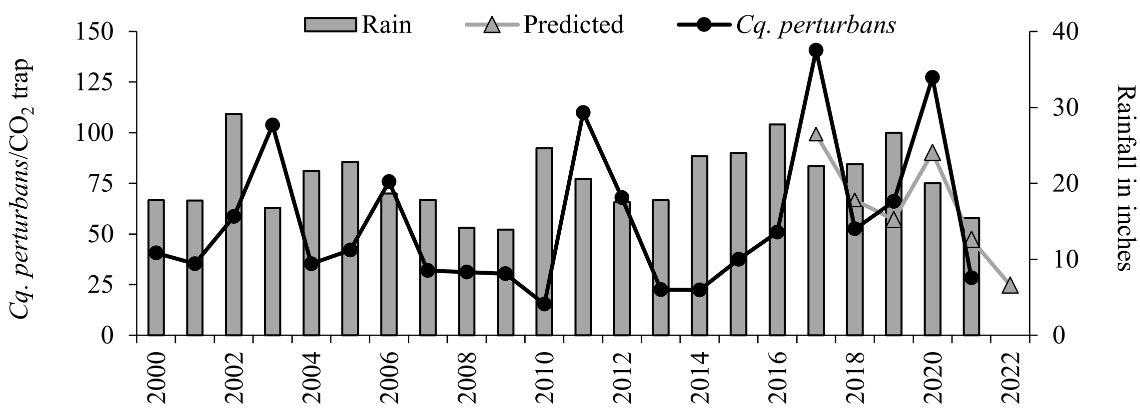


Figure 1.15 Average seasonal rainfall per gauge, average number of *Coquillettidia perturbans* in CO_2 traps, 2000-2021, and predicted amounts for 2017 and beyond.

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.

Culex erraticus The first *Cx. erraticus* adult specimens weren't collected until 1988 when four were detected in NJ light trap samples. Since then, we have been detecting *Cx. erraticus* adults sporadically. Numbers have remained relatively low, but in 2012, 650 adults were collected (Fig 1.16). From 2013 to 2020 the total collected have ranged between 2-33. In 2021, we collected 368 adult *Cx. erraticus* (Fig. 1.16), second to the number collected in 2012 (both hot, dry summers).

Culex erraticus larvae were detected in 1961 (one sample from Washington County) and again in 2012 (six sites in Washington and Scott counties). In 2021, one larval specimen was collected in Scott County by a Twin Lakes Middle School student! MMCD partners with a teacher from the Prior Lake School District on a science unit focused on mosquitoes and mosquito control; of the 300 larval samples they collected, one sample contained one *Cx. erraticus*.

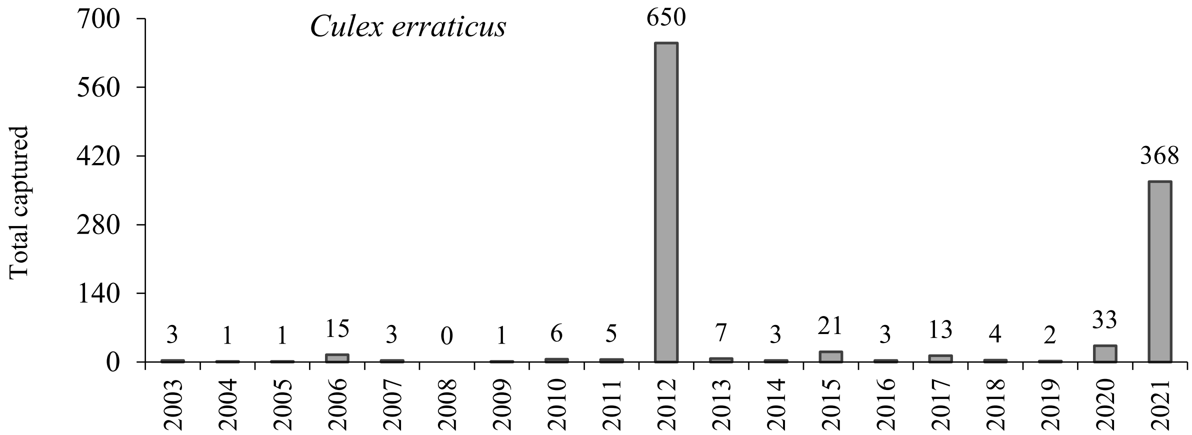


Figure 1.16 Total yearly *Culex erraticus* collected from Monday Night CO_2 traps (low, high, and any outside District), 2002-2021.

Anopheles quadrimaculatus *Anopheles quadrimaculatus* is no longer considered rare in the District. A marked increase in numbers was first detected in 2006 and populations have been detected at higher levels since then (Fig. 1.17). The average collected per year from 2002-2009 is 104.87 and the average collected per year from 2010-2021 is 2,555.75.

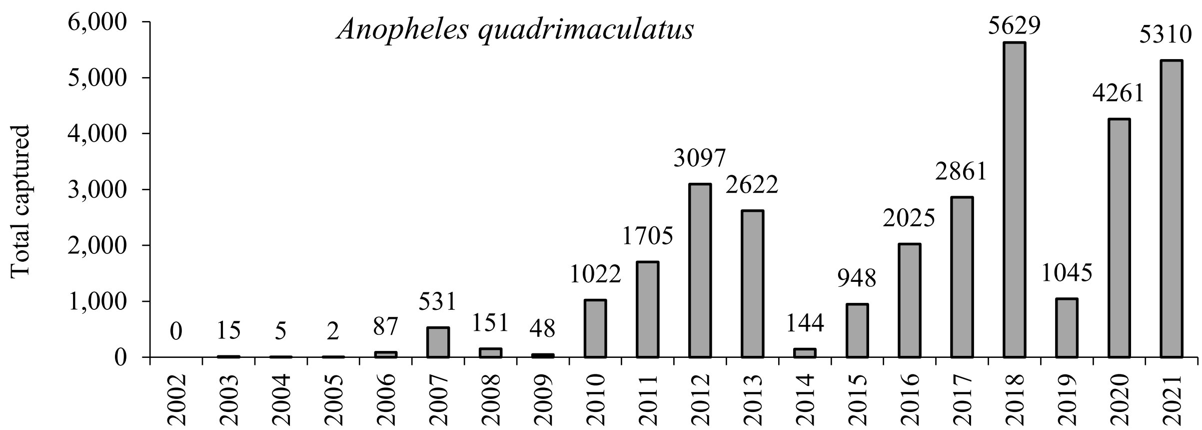


Figure 1.17 Total yearly *An. quadrimaculatus* collected from Monday Night CO_2 traps (low, high, and any outside District), 2002-2021.

Psorophora Adult *Psorophora ferox* and *Ps. horrida* numbers have also been increasing (Fig. 1.18) since 2010. From 2005-2009, 205 *Psorophora* spp. specimens were collected and from 2010-2020, 6,912 were collected. The drought conditions reduced the number of these floodwater mosquitoes in 2021: Only 245 were detected throughout the District this year.

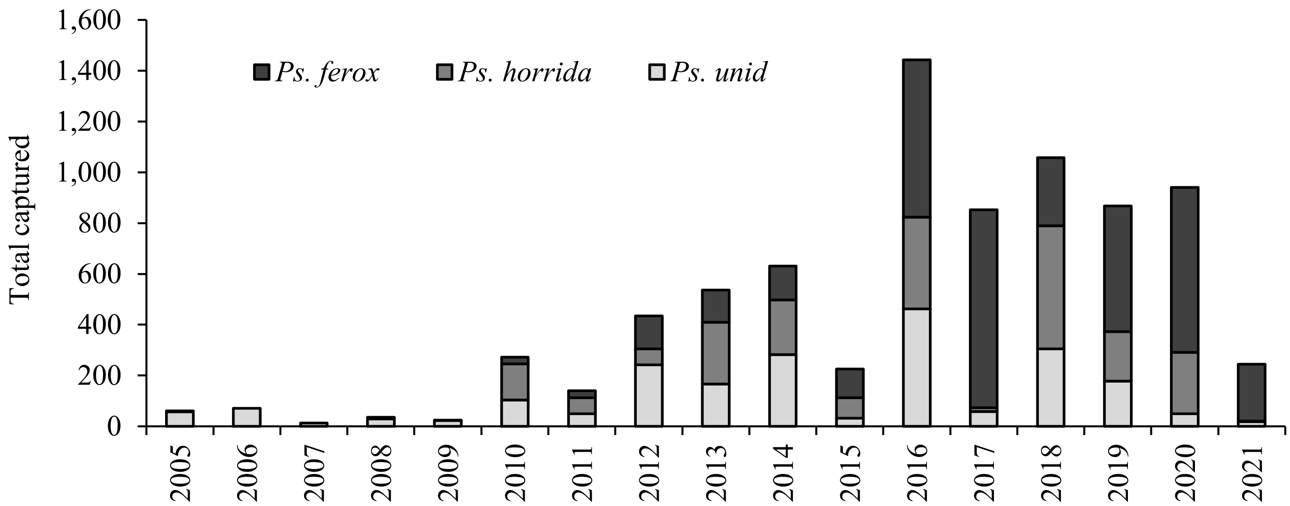


Figure 1.18 Total yearly *Ps. ferox, Ps. horrida,* and *Ps. ferox/horrida* (*Ps. unid*) collected from Monday Night CO_2 traps (low, high, and any outside District), 2005-2021.

2022 Plans – Surveillance

Surveillance will continue as in past years with possible adjustments to monitor disease vectors in the District. We will evaluate sweep net, CO_2, and gravid trap locations to ensure adequate distribution and that target species are collected. We will also evaluate the long-term CO_2 trap network. Finally, we will begin to transfer our archived surveillance data, which are currently in legacy formats (hard copy and outdated computer programs), to the new cloud database. This will enable us to analyze historical data and more easily share MMCD historical surveillance information with other organizations.

Chapter 2 Mosquito-borne Disease

2021 Highlights

- There were 27 WNV cases reported in Minnesota residents, 22 in District residents
- There were six JCV cases reported in Minnesota, four in District residents
- Eastern equine encephalitis was diagnosed in one Minnesota horse
- WNV was detected in 60 District mosquito samples
- MMCD collected and recycled 10,939 tires

2022 Plans

- Continue to provide surveillance and control for La Crosse encephalitis prevention
- Work with others to better understand Jamestown Canyon virus transmission
- Continue catch basin larvicide treatments to manage WNV vectors
- Communicate disease prevention strategies to other local governments
- Continue surveillance for WNV and other mosquito-borne viruses
- Continue to monitor for *Ae. albopictus* and other exotic species
- Continue *Cs. melanura* surveillance and 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), a possible vector *Aedes japonicus* (Japanese rock pool mosquito), 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. Routine surveillance for the invasive species *Aedes albopictus* (Asian tiger mosquito) detects infestations of this potential disease vector.

Culex species are vectors of WNV, a human disease-causing 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 transmit it to a human in a subsequent feeding.

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

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

2021 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 2021, District staff recycled 10,939 tires that were collected from the field (Table 2.1). Since 1988, the District has recycled 711,316 tires. In addition, MMCD eliminated 1,086 containers and filled 162 tree holes (Table 2.1). This reduction of larval habitats occurred through inspection of public and private properties and while conducting a variety of mosquito, tick, and black fly surveillance and control activities.

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

Year	Tires	Containers	Tree holes	Total
2010	23,445	5,880	275	29,600
2011	17,326	3,250	219	20,795
2012	21,493	3,908	577	25,978
2013	17,812	2,410	386	20,608
2014	21,109	3,297	478	24,884
2015	24,127	2,595	268	26,990
2016	18,417	1,690	261	20,368
2017	14,304	1,809	298	16,411
2018	9,730	1,993	478	12,201
2019	9,763	1,611	395	11,769
2020	11,824	3,134	375	15,333
2021	10,939	1,086	162	12,187

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 2021, there were 37 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 2021, MMCD staff collected 1,959 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 141 aspirator samples. Adulticides were applied to wooded areas in 18 of those cases. Adult *Ae. triseriatus* were captured in 309 of 1,516 wooded areas sampled. The mean *Ae. triseriatus* capture was the lowest observed since 2007 (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
2002	1,343	573	42.7	2,058	1.70
2003	1,558	470	30.2	2,676	1.20
2004	1,850	786	42.5	3,101	1.34
2005	1,993	700	35.1	2,617	0.84
2006	1,849	518	28.0	2,680	0.78
2007	1,767	402	22.8	2,345	0.42
2008	1,685	495	29.4	2,429	0.64
2009	2,258	532	24.0	3,125	0.56
2010	1,698	570	33.6	2,213	0.89
2011	1,769	566	32.0	2,563	0.83
2012	2,381	911	38.3	3,175	1.10
2013	2,359	928	39.3	2,905	1.22
2014	2,131	953	44.7	2,543	1.45
2015	1,272	403	31.7	1,631	0.72
2016	1,268	393	31.0	1,590	0.75
2017	1,173	361	30.8	1,334	0.98
2018	1,211	374	30.9	1,394	0.75
2019	1,055	342	32.4	1,170	0.97
2020	1,604	437	27.2	2,001	0.57
2021	1,516	309	20.4	1,959	0.42

Aspirator sampling began during the week of May 17 and continued through the week of September 6. 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 the season peak of 1.06 *Ae. triseriatus* per sample during the week of July 5.

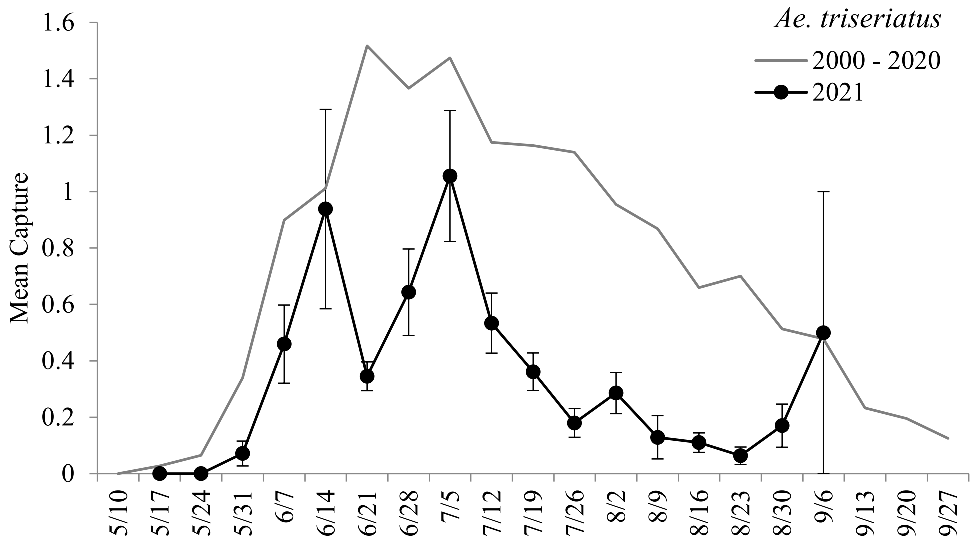


Figure 2.1 Mean number of *Ae. triseriatus* adults in 2021 aspirator samples plotted by week compared to mean captures for the corresponding weeks of 2000-2020. Dates listed are Monday of each week. Error bars equal ± 1 standard error of the mean.

La Crosse Encephalitis in Minnesota There were no LAC cases reported in Minnesota in 2021. Since 1970, the District has had an average of 1.96 LAC cases per year (range 0-10, median 2). Since 1990, the mean is 1.25 cases per year (range 0-8, median 0).

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

Aedes albopictus *Aedes albopictus* were collected in 31 samples in 2021. All of the samples were collected from a tire recycling facility or adjacent properties in Scott County. Specimens were reared from 16 ovitrap samples collected from June 30 to November 1. Seven gravid trap samples contained *Ae. albopictus*; specimens were collected from July 1 to September 22. Six BG Sentinel samples contained the species with collections occurring from August 4 to September 29. Two aspirator samples collected on August 11 and August 25 contained *Ae. albopictus*. A total of 35 specimens were collected in the 15 samples that contained adult *Ae. albopictus*. The high capture was eight in a BG Sentinel trap on August 4.

Routine surveillance of tires and containers in and near the area where *Ae. albopictus* were collected by other methods did not result in the collection of *Ae. albopictus* larvae in 2021.

This was the 19^{th} year and tenth 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 2021, the *Ae. japonicus* population was negatively impacted by the drought conditions. *Aedes japonicus* larvae were found in 278 samples. Most were from containers (127), and tires (57). Larvae were found in samples from 42 stormwater structures/artificial ponds, 30 catch basins, 21 wetlands, and one tree hole, as well.

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 2021, we observed a decrease in *Ae. japonicus* collections from the previous year (Fig. 2.2), due in great part to summer drought. *Aedes japonicus* have been collected less frequently from tree holes than in tires and containers. Of 12 larval samples from tree holes, only one contained the species in 2021.

Aedes japonicus adults were identified in 376 samples. They were found in 168 aspirator samples, 130 gravid trap samples, 65 CO_2 trap samples, eight two-minute sweep samples, five BG Sentinel trap samples. Those totals will likely increase once processing of the New Jersey trap samples is complete.

In 2021, the rate of capture of *Ae. japonicus* in aspirator samples remained near average until mid-July, when collections fell below historical averages (Fig. 2.3). For comparison, the 2011 to 2020 average represents the period when *Ae. japonicus* has occupied parts of all seven District counties. the 2014–2020 average represents the period when the species has been found consistently throughout all areas of the District. The peak rate of capture in 2021 occurred during the week of August 30 at 0.6 *Ae. japonicus* per sample.

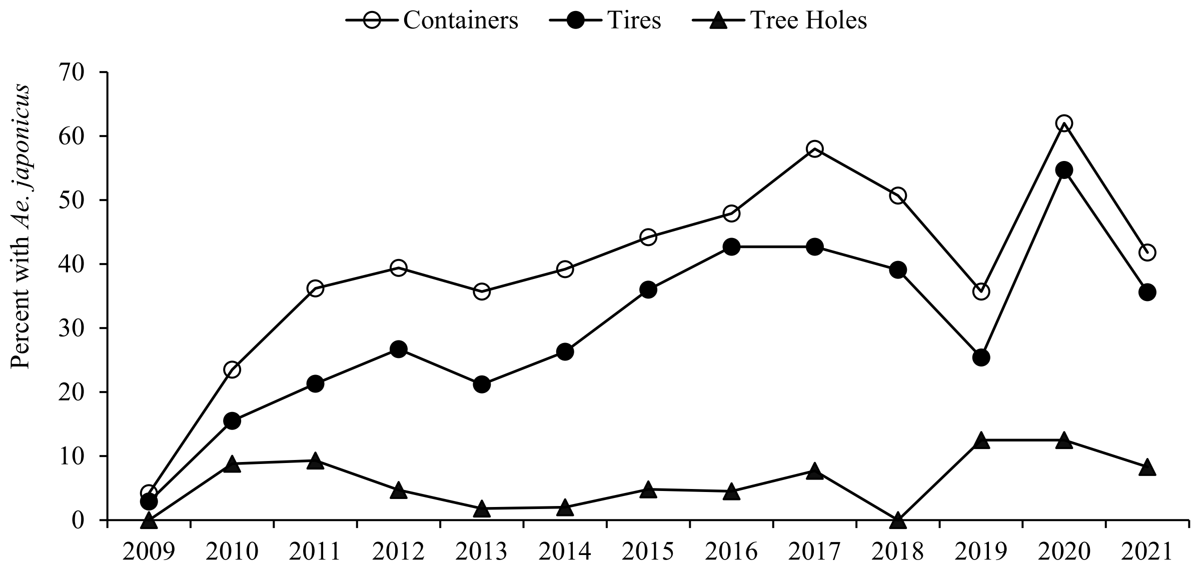


Figure 2.2 Percentage of larval samples from containers, tires, and tree holes containing *Ae. japonicus* by year.

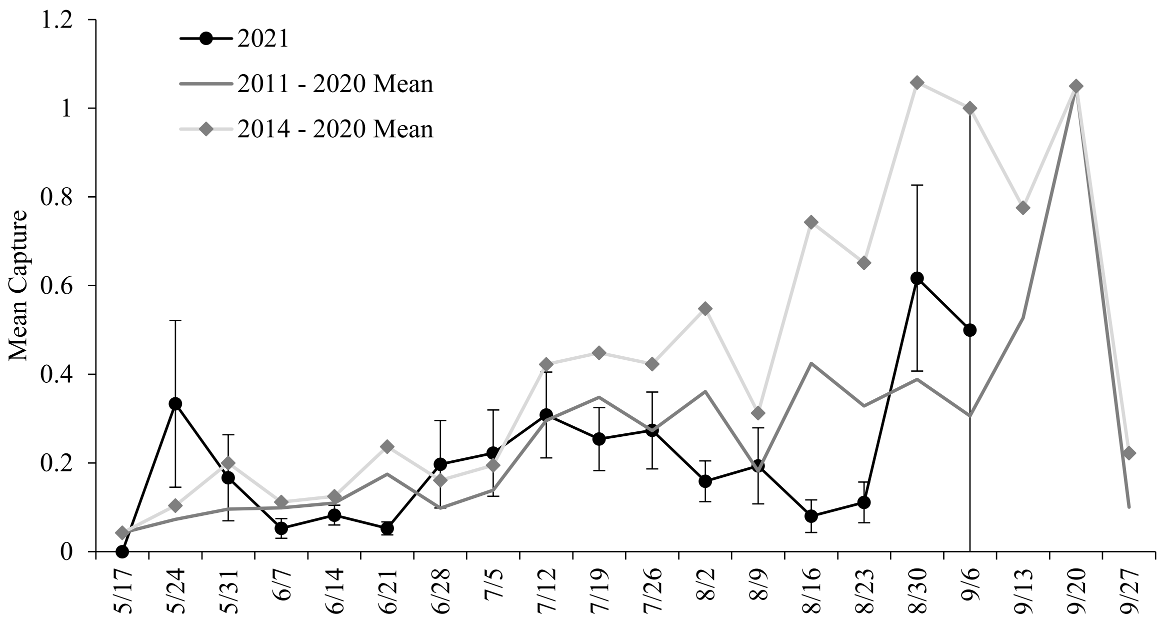


Figure 2.3 Mean number of *Ae. japonicus* adults in 2021 aspirator samples plotted by week compared to mean captures for the corresponding weeks of 2011-2020 and 2014-2020. Dates listed are Monday of each week. Error bars equal ± 1 standard error of the mean.

West Nile Virus (WNV)

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

WNV in the United States West Nile virus was detected in 48 states in 2021. The U.S. Centers for Disease Control and Prevention received reports of 2,445 West Nile illnesses from 47 states and the District of Columbia. There were 165 fatalities attributed to WNV infections. Arizona reported the greatest number of cases with 1,426. Nationwide screening of blood donors detected WNV in 322 individuals from 29 states.

WNV in Minnesota The Minnesota Department of Health confirmed 27 WNV illnesses in residents of Minnesota in 2021. Additionally, there were two reports of WNV illness in horses in Minnesota.

WNV in the District There were 22 WNV illnesses reported in residents of the District in 2021. Since WNV arrived in Minnesota, the District has experienced an average of 10.0 WNV illnesses each year (range 0-25, median 8). When cases with suspected exposure locations outside of the District are excluded, the mean is 8.1 cases per year (range 0-22, median 6).

Surveillance for WNV - Mosquitoes Surveillance for WNV in mosquitoes began during the week of May 31 and continued through the week of September 27. Several mosquito species from 44 CO_2 traps (12 elevated into the tree canopy) and 37 gravid traps were processed for viral analysis each week. In addition, we processed *Cx. tarsalis* collected by any of the CO_2 traps in our Monday night network for viral analysis. MMCD tested 857 mosquito pools using the rapid analyte measurement platform (RAMP®), 60 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, 2021. 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	209	18	0	0.00
Cx. pipiens	747	34	7	9.37
Cx. restuans	2,035	58	2	0.98
Cx. salinarius	204	14	0	0.00
Cx. tarsalis	3,153	221	7	2.22
Cx. pipiens/Cx. restuans	6,131	266	20	3.26
Culex species	6,125	246	24	3.92
Total	18,604	857	60	3.23

Even though late spring and early summer weather conditions were nearly ideal for rapid amplification of WNV, the virus remained undetected in mosquitoes until the week of July 19 when seven samples returned positive results. Positive samples that week were *Cx. pipiens*, *Cx. restuans*, or combinations of the two species collected in Dakota, Hennepin, and Ramsey counties. The first WNV positive pool of *Cx. tarsalis* was collected the following week in Hennepin County. Of the season's 60 WNV positive mosquito samples, 22 were collected in Hennepin Co., 15 in Ramsey Co., 13 in Anoka Co., seven in Dakota Co., two in Scott Co., and one in Washington Co.

Prior to 2021, the mean date of the first WNV detection in mosquitoes in the District was July 11 and the median date was July 6. West Nile virus circulated at very low levels in the District in 2020 likely resulting in few chronically infected mosquitoes overwintering and re-emerging in 2021. Thus, despite exceptionally warm weather in parts of May and June, the virus remained undetected by the District's mosquito surveillance network through mid-July. Following the first WNV positive samples during the week of July 19, the virus was detected in mosquitoes each of the next nine weeks. (Fig. 2.4). The minimum WNV infection rate (MIR) in mosquitoes peaked during the week of September 20 at 14.29 per 1,000 mosquitoes tested.

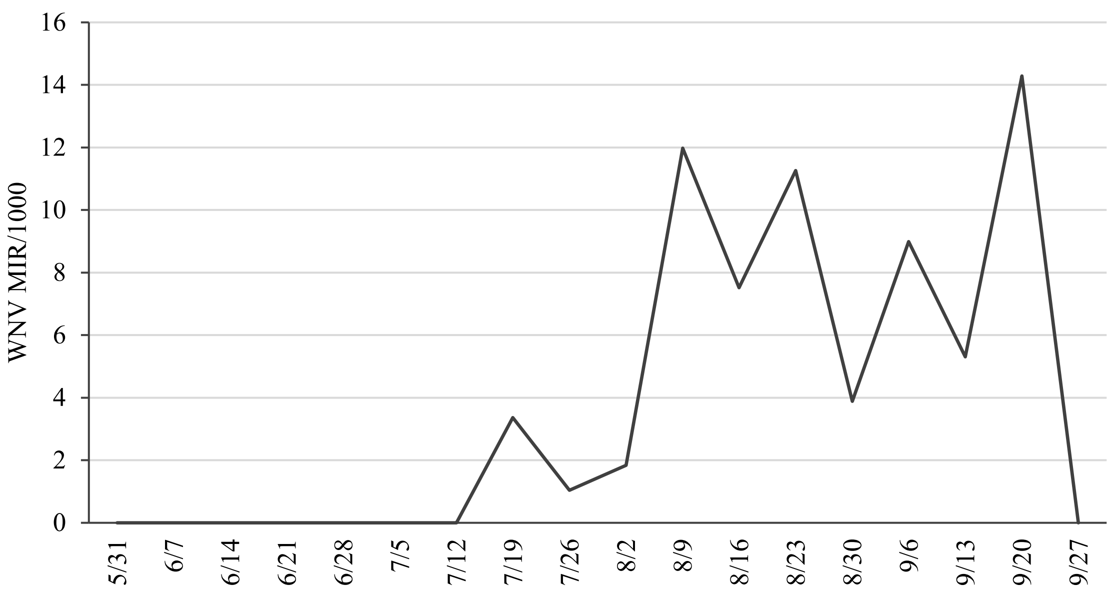


Figure 2.4 Weekly minimum WNV infection rates (MIR) per 1,000 *Culex* specimens tested in 2021. Dates listed are the Monday of each sampling week.

Surveillance for WNV - Birds The District received 34 reports of dead birds by telephone, internet, or from employees in the field in 2021. Thirty-one of the birds reported were corvids, 23 were American crows and eight were blue jays. No birds were tested by MMCD for WNV in 2021.

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 in the low to moderate range throughout the 2021 season. Weekly mean collections peaked at 6.4 *Cx. tarsalis* per sample on August 16 (Fig. 2.5). As is typical, few *Cx. tarsalis* were captured by gravid trap in 2021.

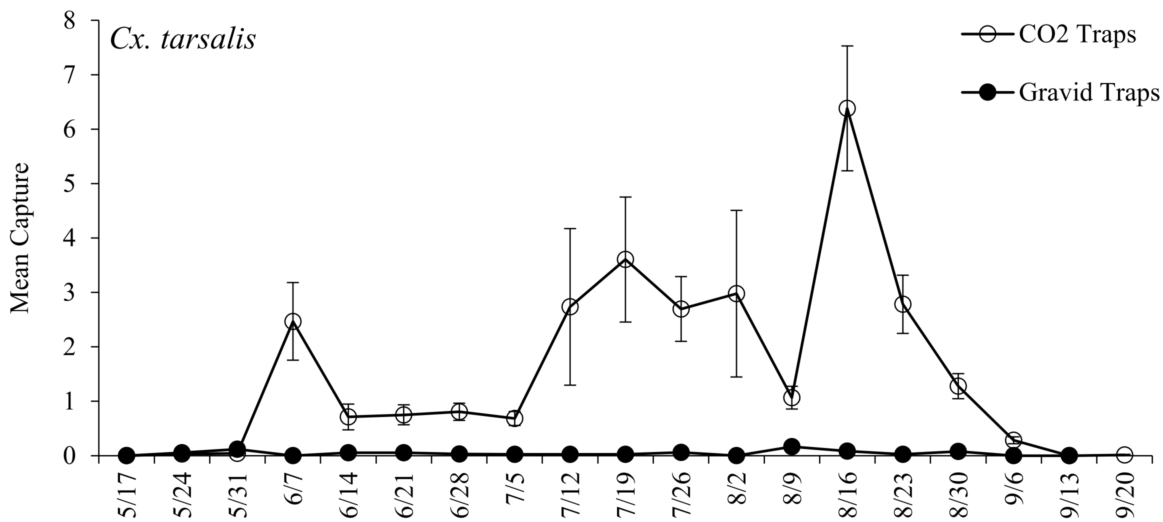


Figure 2.5 Average number of *Cx. tarsalis* in CO_2 traps and gravid traps, 2021. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

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. Surveillance in 2021 indicated the *Cx. restuans* population was high early in the season (Fig. 2.6). The CO_2 trap captures peaked on June 7 at 3.7 per trap. Gravid trap collections of *Cx. restuans* were elevated for three weeks from early to mid-June. The peak rate of capture occurred during the week of May 31 at 21.5 per trap.

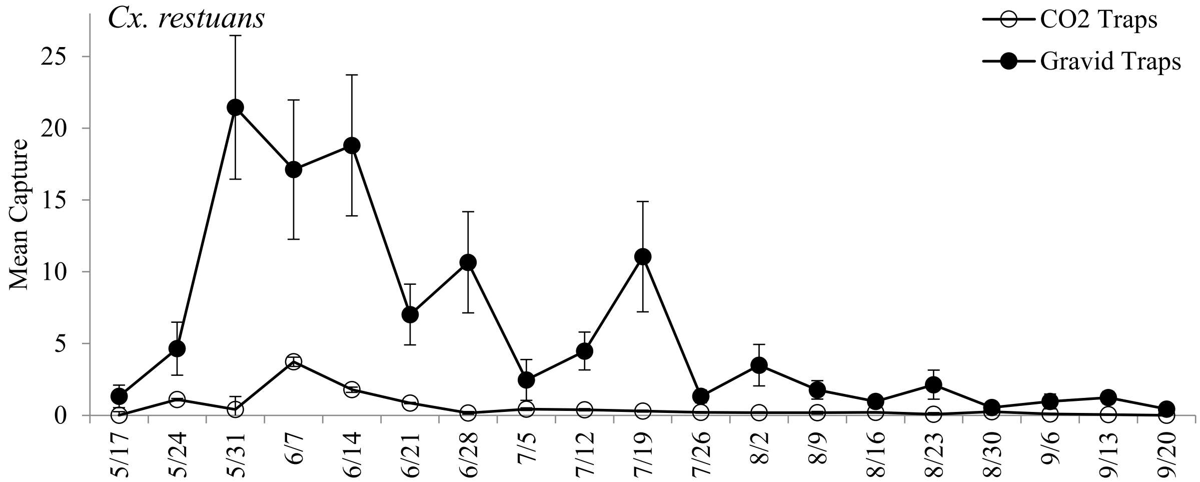


Figure 2.6 Average number of *Cx. restuans* in CO_2 traps and gravid traps, 2021. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

Culex pipiens are important WNV vectors in much of the United States. This species prefers warmer temperatures than *Cx. restuans*; therefore, populations of *Cx. pipiens* in the District tend to remain low in early to mid-summer and peak late in the summer when temperatures are typically warmer. In 2021, collections of *Cx. pipiens* in both CO_2 traps and gravid traps occurred at moderate levels (Fig. 2.7). The rate of capture peaked at 9.1 per gravid trap during the week of August 2 and at 1.3 per CO_2 trap during the week of August 30.

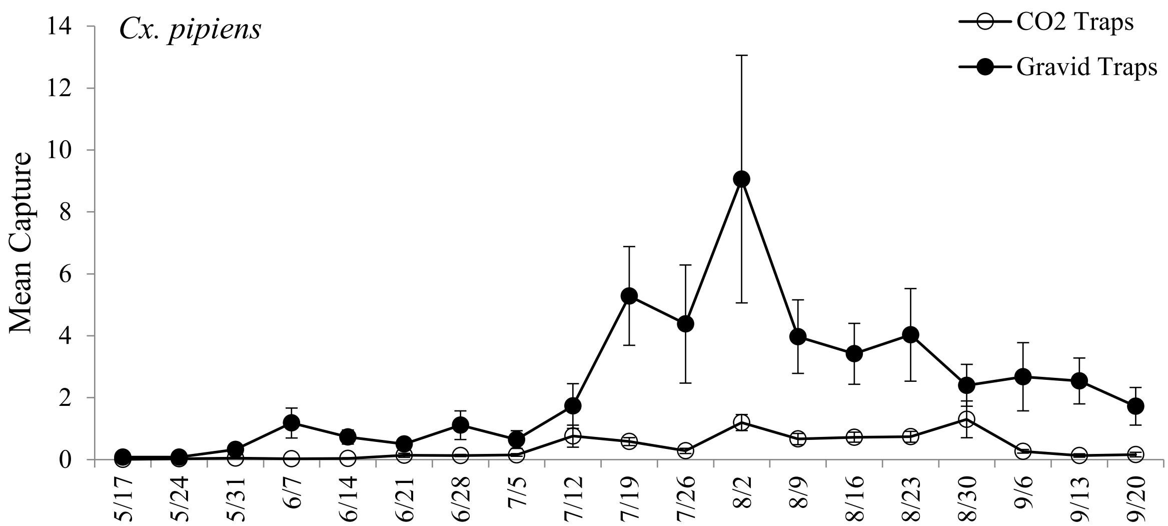


Figure 2.7 Average number of *Cx. pipiens* in CO_2 traps and gravid traps, 2021. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

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 2021 and likely consisted of mostly *Cx. restuans* until early July and mostly *Cx. pipiens* thereafter.

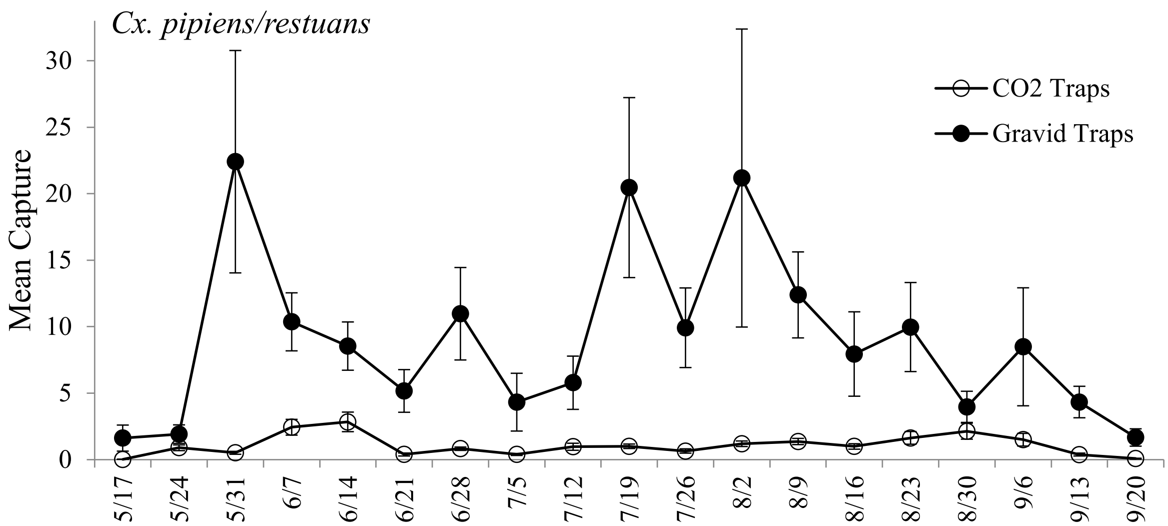


Figure 2.8 Average number of *Cx. pipiens/restuans* in CO_2 traps and gravid traps, 2021. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

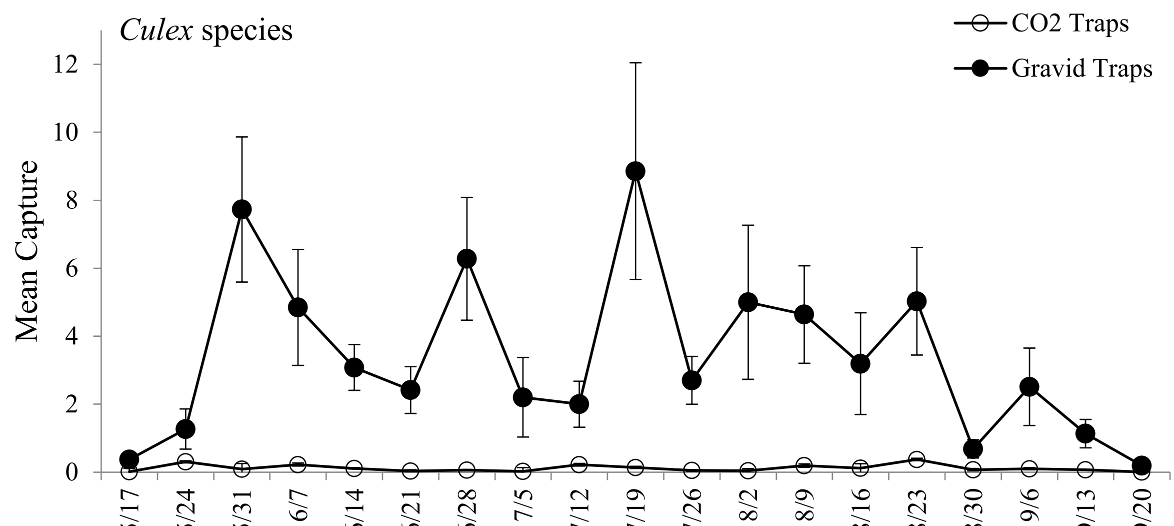


Figure 2.9 Average number of *Culex* species in CO_2 traps and gravid traps, 2021. Dates are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

Larval *Culex* Surveillance

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

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

Inspectors collected 1,236 larval samples from stormwater structures and other constructed habitats. *Culex* vectors were found in 83.2% of the samples in 2021 (Table 2.4). *Culex pipiens* were found more frequently than during the previous two seasons. 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 2017-2021

	Yearly percent occurrence				
Species	2017 (N=627)	2018 (N=765)	2019 (N=664)	2020 (N=404)	2021 (N=1,236)
Cx. pipiens	39.7	46.5	5.4	24.0	40.8
Cx. restuans	60.0	63.7	75.0	59.9	65.8
Cx. salinarius	0.5	0.0	0.0	0.0	0.0
Cx. tarsalis	3.2	1.4	3.2	0.7	3.5
Any *Culex* vector spp.	74.6	81.2	79.7	71.0	83.2

Mosquito Control in Underground Stormwater Structures Many stormwater management systems include large underground chambers to trap sediments and other pollutants. There are several designs in use that vary in dimension and name, but collectively they are often referred to as BMPs from *Best Management Practices for Stormwater* under the 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 2021, we continued the cooperative mosquito control plan for underground habitats. Eighteen municipalities volunteered their staff to assist with material applications (Table 2.5).

Altosid® XR briquets were used at the label rate of one briquet per 1,500 gallons of water retained. Briquets were placed in 1,055 underground habitats.

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

Table 2.5 Cities that assisted in treating underground stormwater habitats in 2021; 1,055 structures were treated with a total of 1,157 briquets

City	Structures treated	Briquets used	City	Structures treated	Briquets used
Bloomington	86	94	Mendota Heights	19	20
Brooklyn Park	4	15	Minneapolis	175	175
Columbia Heights	12	16	New Brighton	5	8
Eagan	61	61	Prior Lake	66	66
Eden Prairie	12	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	Woodbury	62	62

Larval Surveillance in Catch Basins Catch basin larval surveillance began the week of May 24 and ended the week of September 20. Larvae were found during 471 of 566 catch basin inspections (83.2%) in 2021 (Fig. 2.10).

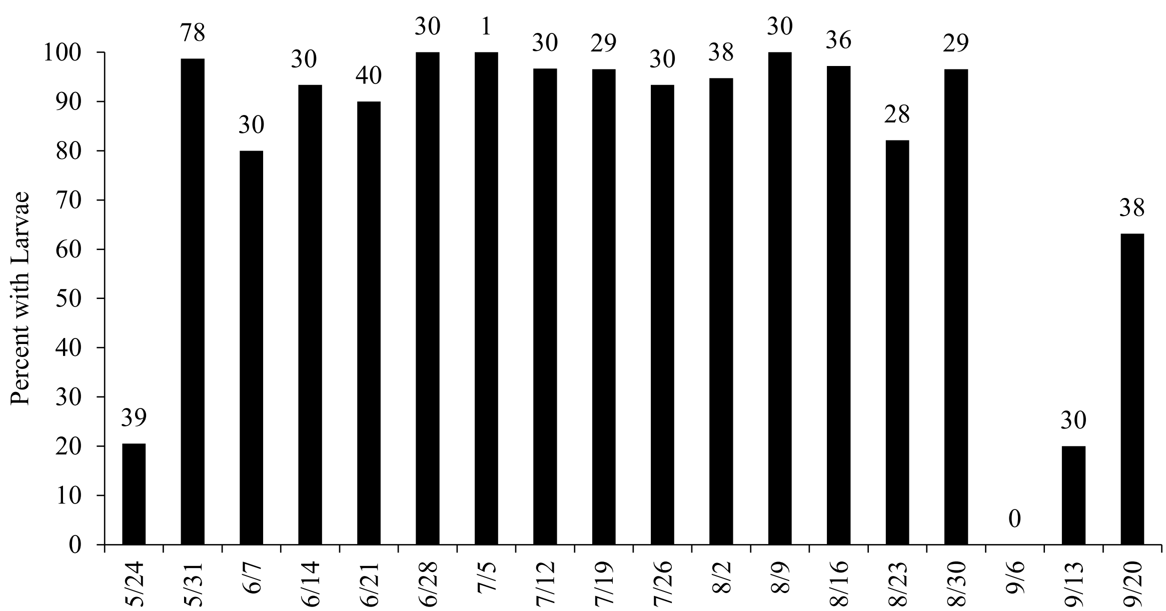


Figure 2.10 Percent of catch basins inspected with mosquitoes present in 2021. Bars are labeled with the number of inspections occurring during the week. Excludes surveillance of sites treated with the larvicides VectoLex® FG and VectoLex® WSP.

Mosquito larvae were identified from 894 catch basin samples. *Culex restuans* were found in 52.8% of catch basin larval samples. *Culex pipiens* were found in 42.1% of samples. At least one *Culex* vector species was found in 95.9% of samples. *Culex restuans* were collected more frequently than *Cx. pipiens* until the week of July 19 when *Cx. pipiens* became more prevalent (Fig. 2.11).

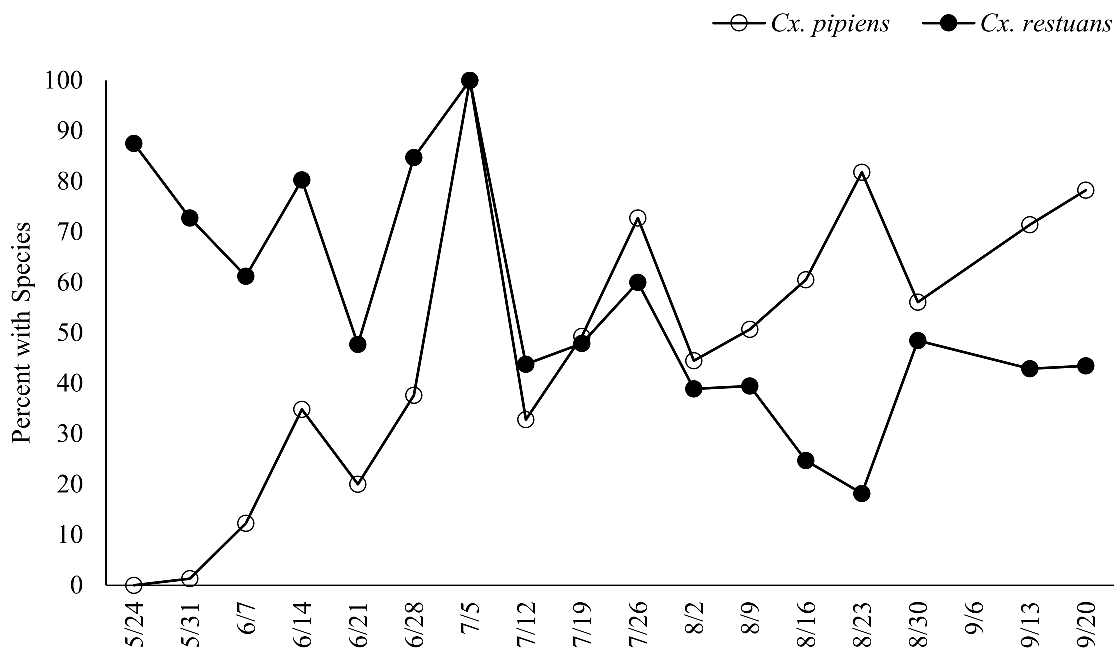


Figure 2.11 Percent occurrence of *Cx. pipiens* and *Cx. restuans* in catch basin larval samples by week. No sampling occurred during the week of September 6.

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 routinely detected antibodies to the EEE virus in wolves, moose, and elk in northern Minnesota.

In 2021, four human EEE illnesses were reported to CDC from three states. Two of the illnesses occurred in Georgia, one in South Carolina, and one in Wisconsin. There were veterinary reports of EEE activity in 15 states. A total of 110 EEE illnesses in horses were reported. Nine states reported EEE positive findings from mosquito samples.

One of the equine EEE illnesses reported in 2021 occurred in Minnesota, in Itasca County. This was the third consecutive year with at least one equine EEE case in Minnesota.

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

Surveillance for adults by CO_2 trap and aspirator indicated the 2021 *Cs. melanura* population was low. Four pools containing 24 *Cs. melanura* were tested in the MMCD lab for EEE using the VecTOR Test Systems EEE virus antigen assay kit. All samples were negative for EEE.

District staff monitored adult *Cs. melanura* at 10 locations using 11 CO_2 traps (see Chapter 1, Fig. 1.5). Five sites are in Anoka County, four sites are in Washington County, and one site is in Hennepin County. *Culiseta melanura* have been collected from each location in the past. Two traps are placed at the Hennepin County location – one at ground level and one elevated 25 feet into the tree canopy, where many bird species roost at night. The first *Cs. melanura* adults were collected in CO_2 traps during the week of June 14 (Fig. 2.12). The population remained low throughout the season with a maximum capture of 0.55 per trap during each of the last three weeks of surveillance.

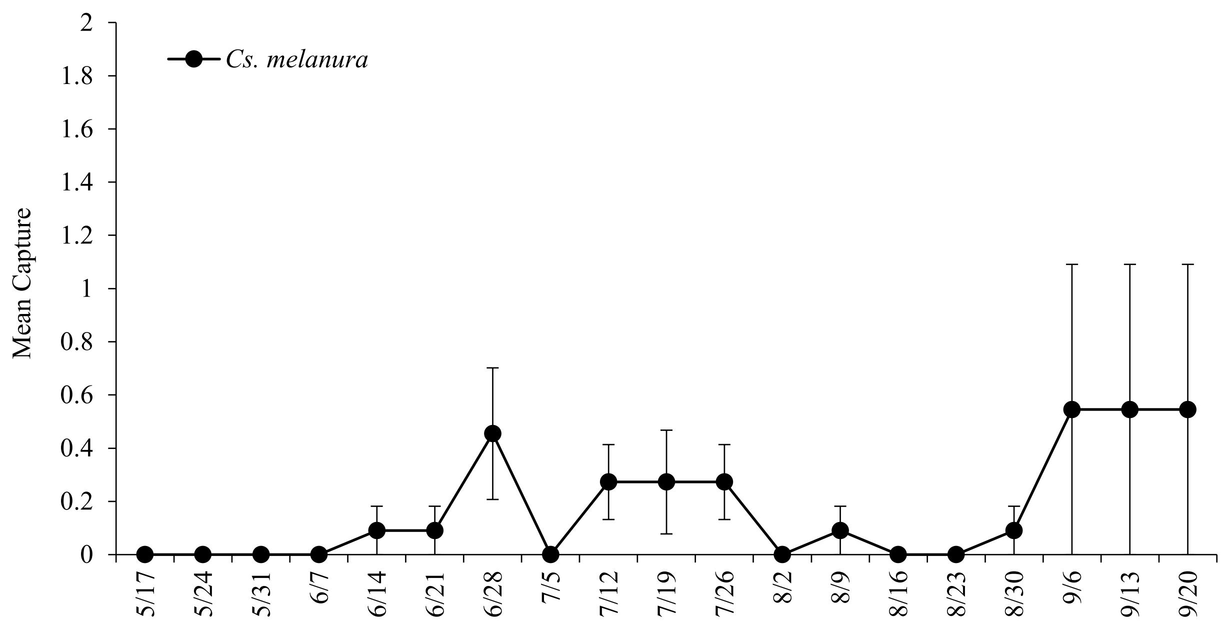


Figure 2.12 Mean number of *Cs. melanura* adults in CO_2 traps from selected sites, 2021. Dates listed are the Monday of each sampling week. Error bars equal ± 1 standard error of the mean.

Staff collected a season total of only 52 *Cs. melanura* in 132 aspirator samples from wooded areas near bog habitats. The first aspirator collections of *Cs. melanura* occurred during the week of June 21 (Fig. 2.13). *Culiseta melanura* adults were collected during just three of the 16 weeks with aspirator samples. The peak rate of capture was 1.9 *Cs. melanura* per sample during the week of June 21.

Culiseta melanura develop primarily in bog habitats in the District, and larvae can be difficult to locate. In 2021, *Cs. melanura* larvae were found in four of nine sites surveyed for the species.

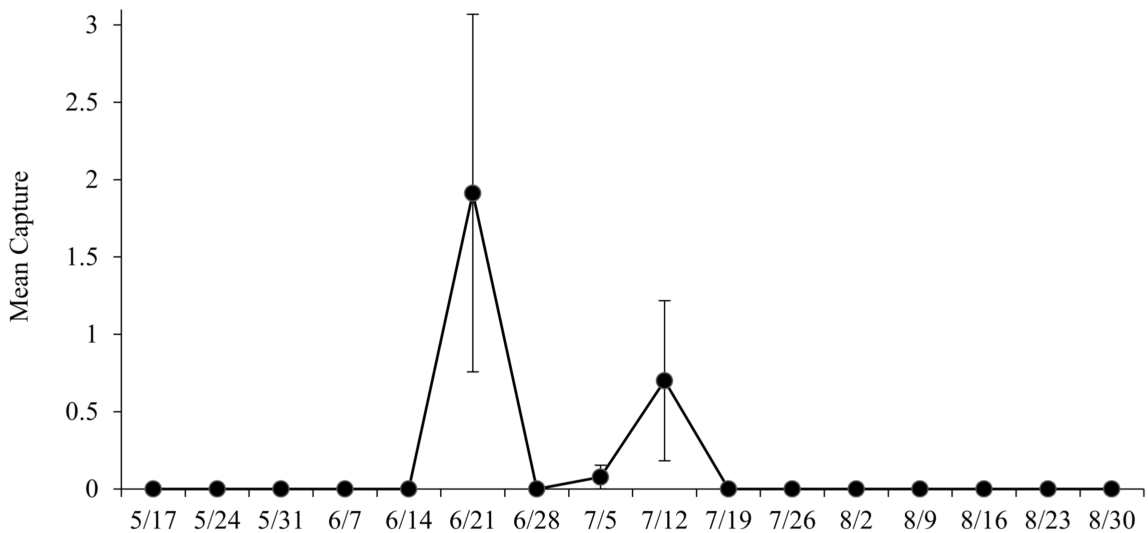


Figure 2.13 Mean number of *Cs. melanura* in 2021 aspirator samples plotted by week. Dates listed are Monday of each week. Error bars equal ± 1 standard error of the mean.

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 in southern Minnesota. The virus has not been detected in Minnesota since then. *Culex tarsalis* collections were in the low to moderate range in the District in 2021 (Fig. 2.5).

Jamestown Canyon Virus (JCV)

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

Twenty-three JCV cases were reported nationally from seven states in 2021. There were six JCV illnesses reported in Minnesota. Three of the illnesses were reported in District residents, two from Hennepin County and one from Ramsey County.
Over the past four seasons, MMCD has partnered with the Midwest Center of Excellence for Vector-borne Disease (MCE-VBD) to investigate JCV transmission in the region. Mosquitoes collected by MMCD have been tested at MCE-VBD for JCV. In 2018, one of 428, in 2019 one of 336, and in 2020 one of 88 mosquito samples tested were positive for the virus. In 2021 we submitted 48 samples to MCE-VBD for JCV analysis. Results are pending.

2022 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

2021 Highlights-preliminary

- Number of sites positive for *Ixodes scapularis* was 59
- Average *I. scapularis* per mammal was 0.718
- No *Amblyomma americanum* were reported to MMCD or the MDH
- Latest tick-borne cases available - 2019 Lyme case total: 915 confirmed cases (source CDC)
- Anaplasmosis cases in 2019 totaled 408 (source CDC)

2022 Plans

- *I. scapularis* surveillance at 100 sampling locations
- Education, identifications, and homeowner consultations
- Update the Tick Risk Meter, provide updates on Facebook, and post signs at dog parks
- Track collections of *Amblyomma americanum* or other new or unusual tick species, including *Haemaphysalis longicornis*
- Participate in the inter-agency collaboration across MN for *H. longicornis* tracking
- Provide samples from mice to Dr. Jeff Bender for SARS-CoV-2 testing
- Collect *I. scapularis* for testing by the CDC

Background

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

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

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

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

2021 Tick-borne Disease Services

Lyme Disease and Human Anaplasmosis

Our tick surveillance began to detect increases in the metro *I. scapularis* population in 1998, with obvious expansion beginning in 2000. Since then, we have often documented new record-setting collection seasons. In parallel, but with a two-year lag (since 2000), the MDH has documented record-setting human tick-borne disease case totals. Pre-2000, the highest Lyme disease case total was 302 but since 2000 the Lyme disease totals have ranged from 463 to 1,431 cases. The typical average is >1,000 per year. Human anaplasmosis cases have also risen. After averaging roughly 15 cases per year through 1999, the total HA case numbers ranged from 78 to 186 from 2000-2006 then increased into the range of the 300s. The all-time high, statewide Lyme disease case record (1,431) was set in 2013. The all-time high HA record of 788 was set in 2011. Case totals since 2018 have not yet been tabulated by the MDH due to the ongoing SARS-CoV-2 pandemic. The CDC reported 915 confirmed Lyme disease cases (and 613 probable cases) and 408 HA cases (confirmed and probable) in 2019, both lower than in 2018.

Ixodes scapularis Distribution Study

The District continued to sample the network of 100 sites set up in 1991-1992 to monitor potential changes in tick distribution over time. As in previous years, the primary sampling method involved capturing small mammals from each site and removing any attached ticks from them. Collections from the northeastern metropolitan area (primarily Anoka and Washington counties) have consistently detected *I. scapularis* since 1990, and in 1998 *I. scapularis* was detected in Hennepin and Scott counties for the first time. We collected at least one *I. scapularis* from all seven counties that comprise our service area for the first time in 2007. Since then, *I. scapularis* has been detected with greater frequency and they are prevalent now in many wooded areas south of the Mississippi River. The 2021 Lyme Tick Distribution Study report will be available on our website in June (http://mmcd.org/publications/). Following are some preliminary 2021 highlights.

The 2021 average number of *I. scapularis* collected per mammal (0.72) is higher than all of our averages tabulated from 1990-1999 (range 0.09-0.41) and similar to many of our yearly averages tabulated since 2000, except for 2005, 2014-2018 and 2020 which were all > 1.00 (Table 3.1). Our record yearly average of 1.68 occurred in 2016. In 2021, as in all years from 2007-2021 except for 2011, we had collected at least one *I. scapularis* from all seven counties of our service area. There were 59 positive sites, a slightly lower total than the totals of the previous seven years. Our yearly positive site totals from 2000-2009 were typically in the 50s. The first time we had a site total of 70 or more was in 2010, then through 2014 our totals were either in the 50s or 70s. The first time we tabulated a site total of 80 or more was in 2015 when we had 81 positive sites, and our record high of 82 positive sites was set in 2016. Maps are included in our yearly Lyme tick distribution study report.

Table 3.1 Yearly totals of the number of mammals trapped and ticks collected (by tick species and life stage), and the average number of *Ixodes scapularis* per mammal, 1990-2021 (preliminary); the number of sites sampled was 250 in 1990, 270 in 1991, 200 in 1992, and 100 from 1993 to present.

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

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

Tick-borne Disease Prevention Services

Identification Services and Outreach The overall scope of tick-borne disease education activities and services were again reduced in 2021 but included tick identifications of emailed or mailed ticks, updating our Tick Risk Meter on our website, and providing tick-borne disease information via telephone and on MMCD's Facebook page. See Additional Updates for more.

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

Distributing Materials to Targeted Areas Brochures, tick cards, and/or posters distribution to various locales was again suspended for the 2021 season due to the ongoing pandemic.

Additional Updates – 2021

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

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

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

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

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

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

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

***Amblyomma americanum* (lone star tick)** *Amblyomma americanum* is an aggressive human biter and can transmit bacteria that cause ehrlichiosis, among other potential pathogens. Both the tick and ehrlichiosis are more common to the southern U.S., but the range of *A. americanum* is known to be moving northward. *Amblyomma americanum* ticks have been submitted to MMCD from the public on a rare, sporadic basis, and this species was first collected by MMCD in 1991 via a road-kill examination of a white-tailed deer (*Odocoileus virginianus*). However, in 2009, for the first time in a number of years, the public submitted *A. americanum* to both MDH and MMCD (from Minneapolis and Circle Pines). This trend has continued since, with *A. americanum* submitted to MMCD and/or MDH from a variety of metro and other locations. As part of the tick submission process, each agency makes queries regarding travel history, excluding ticks that may have been picked up elsewhere.

Neither the MMCD nor the MDH received any *A. americanum* in 2021. From 2009-2020, 42 *A. americanum* have been collected or reported to the MMCD and the MDH. In 2017, MMCD had no reports, but the MDH received one report each from Hennepin and Washington counties and three additional reports from outside MMCD's service boundaries. In 2018, MDH received a report of one adult (sex unknown), and collected one adult female in Itasca State Park, outside MMCD's service boundaries. MMCD received one adult female *A. americanum* from Shoreview (Ramsey County). In 2019, MMCD collected one adult female in Scott County and MDH reported one adult female from Washington or Hennepin counties. In 2019, MMCD collected one adult female in Scott County and MDH reported one adult female from Washington or Hennepin counties. In 2020 MMCD collected one adult female each in Dakota and Hennepin counties, with two adult females (one unverified) reported from outside our service area. The MDH reported one adult female each from Ramsey and Anoka counties, five females and three males from outside of our service area, and one unverified report (sex unknown) that had been found in the state of Mississippi.

2022 Plans for Tick-borne Disease Services

Surveillance and Disease Prevention Services

The metro-based *I. scapularis* distribution study that began in 1990 is planned to continue unchanged. We will continue our tick-borne disease education activities and services of tick identifications, homeowner consultations, updating the Tick Risk Meter on our website, and using social media. Post COVID-19 restrictions, we will resume stocking local government agencies, libraries, and other locations with tick cards, brochures, and/or posters, distributing materials at local fairs and the Minnesota State Fair, setting up information booths at events as opportunities arise and will begin re-offering a comprehensive presentation that covers tick biology, diseases transmitted, and prevention measures. We will also continue to post signs at dog parks and other appropriate locations. As in past years, signs will be posted in the spring and removed in late fall after *I. scapularis* activity ceases for the year.

Collaborative Projects

Collaborative Project with the Centers for Disease Control The tick vector surveillance team had dragged for *I. scapularis* in the fall of 2021 for the Centers for Disease Control's (CDC) Rickettsial Zoonoses Branch. The CDC is developing a laboratory technique which will be able to identify *I. scapularis*. This study could also find that some species morphologically identified as *I. scapularis*, like the newly described *Dermacentor similis* in the West, are not actually *I. scapularis* but a new species entirely. The CDC does not have any ticks from Minnesota, so our work is very helpful. Additional collections will be made in the spring of 2022.

Collaborative Project with Jeff Bender, University of Minnesota. SARS in Mice?
Abbey Novotny, North Region, had collected samples for a pilot study test in October 2021. All samples were negative. In 2022, we will again collaborate with Jeff Bender, Veterinarian Epidemiologist (U of M). A subset (100) of our *Peromyscus leucopus* (white-footed mouse) collected for surveillance will be tested for SARS-Cov-2 as part of a multi-year project Dr. Bender has undertaken. While not directly relevant to MMCD's mission of protecting the public from tick-borne disease risk, it poses minimal additional effort along with being very relevant to the current pandemic happening across the globe. Interestingly, researchers have proposed a mouse origin for the progenitor of the Omicron variant (Changshuo, et al., 2021). We plan to minimize impacts to field staff by having them coordinate sample collection with our Technical Services tick coordinator.

Amblyomma americanum and Other New or Unusual Ticks

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

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

References Cited

Changshuo Wei, K-J Shan, W. Wang, S. Zhang, Q. Huan, and W. Qian. 2021. Evidence for a mouse origin of the SARS-CoV-2 Omicron variant. Journal of Genetics and Genomics. 48(12): 1111-1121. DOI: 10.1016/j.jgg.2021.12.003

Chapter 4 Mosquito Control

2021 Highlights

- In 2021, 44,606 fewer acres were treated with larvicide (150,299 acres) than in 2020 (194,911 acres)
- We planned to reinstate about one third of the larval control cut in 2017 because the District's financial situation supported it. Dry conditions reduced service demand
- A cumulative total of 284,774 catch basin treatments were made to control WNV vectors
- In 2021, 3,913 fewer acres of adulticide treatments were made (2,537 acres) than in 2020 (6,450 acres)
- Responding to COVID-19 resulted in 16% fewer seasonal hires because each vehicle can accommodate only one person to maintain social distancing

2022 Plans

- If the economic situation permits, reinstate 100% of the larval control cut in 2017 as part of the expenditure reduction steps
- Continue spring *Aedes* larval surveillance in areas with high adult abundance to target potential Jamestown Canyon vectors
- Continue to collaborate with groups such as Monarch Joint Venture to use Monarch ecology and migration data to mitigate potential impacts of adult mosquito control
- Work closely with the Minnesota Pollution Control Agency to fulfill the requirements of a NPDES permit

Background

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

Due to the large size of the metropolitan region (2,975 square miles), larval control was considered the most cost-effective control strategy in 1958 and remains so today. Consequently, larval control is the focus of the control program and the most prolific mosquito habitats (82,205 potential sites) are scrutinized for all target mosquito species.

Larval habitats are diverse. They vary from small, temporary pools that fill after a rainfall to large wetland acreages. Small sites (ground sites) are three acres or less, which field crews treat by hand if larvae are present. Large sites (air sites) are treated by helicopter only after certain criteria are met: larvae occur in sufficient numbers (threshold), larvae are of a certain age (1-4 instar), and larvae are the target species (human biting or disease vector). We treated a few smaller sites (primarily sites formerly treated when frozen with Altosid® briquets) using a drone (see Chapter 7 for details).

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

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

Three synthetic pyrethroids were used in 2021: permethrin, sumithrin, and etofenprox. Sumithrin (Anvil®) and etofenprox (Zenivex®) can be used in agricultural areas. Local (barrier) treatments are applied to foliage where adult mosquitoes rest (mosquito harborage). Ultralow volume (ULV) treatments employ a fog of very small droplets that contact mosquitoes where they are active. Barrier treatments are effective for up to seven days. ULV treatments kill mosquitoes and dissipate within hours. A description of the control materials is found in Appendix C. Appendix D indicates the dosages of control materials used by MMCD, both in terms of amount of formulated (and in some cases diluted) product applied per acre and the amount of active ingredient (AI) applied per acre. Appendices E and F contains a historical summary of the number of acres treated with each control material. Insecticide labels are located in Appendix G.

The District uses priority zones to focus service in areas where the highest numbers of citizens benefit (Figure 4.1). Priority zone 1 (P1) contains the majority of the population of the Twin Cities metropolitan area and has boundaries similar to the Metropolitan Urban Service Area (MUSA, Metropolitan Council). Priority zone 2 (P2) includes sparsely populated and rural parts of the District. We consider small towns or population centers in rural areas as satellite communities, and they receive services similar to P1. Citizens in P1 receive full larval and adult vector and nuisance mosquito control. In P2, the District focuses on vector control and provides additional larval and adult control services as appropriate and as resources allow.

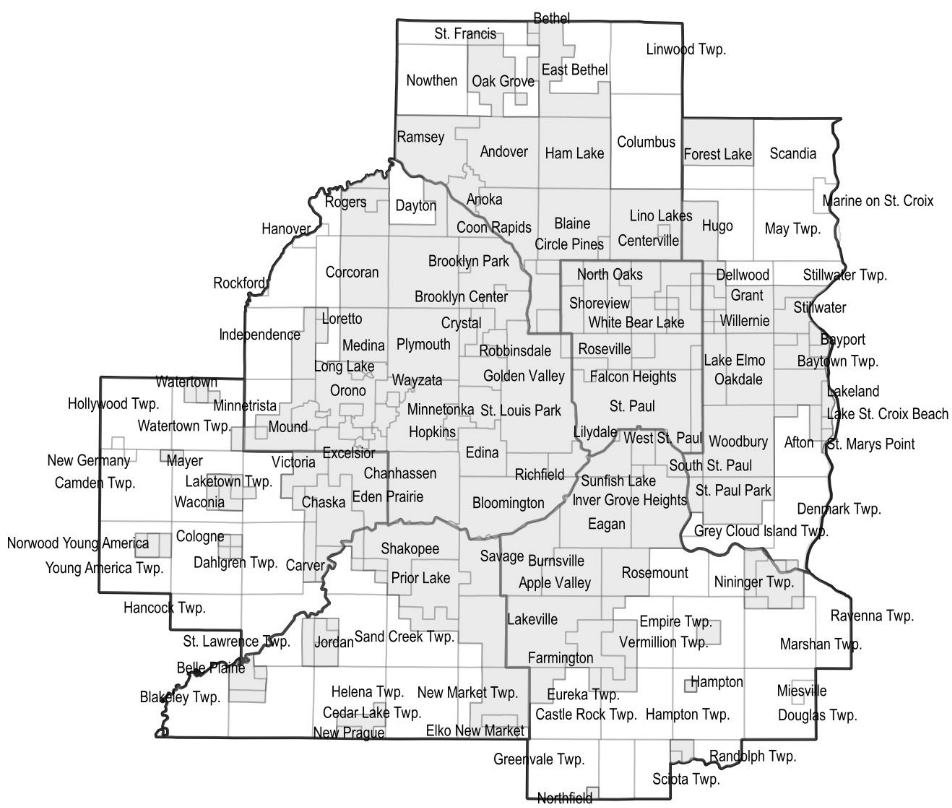


Figure 4.1 Priority zones 1 (shaded-P1) and 2 (white-P2), with District county and city/township boundaries, 2021.

2021 Mosquito Control

COVID-19 Program Impacts

Program Changes in Response to COVID-19-related Budget Limitations Our goal throughout the COVID-19 pandemic has been to provide as many services as possible while maximizing staff and citizen safety by implementing social distancing and all other COVID-19 safety requirements. Forecasts made in April 2020 predicted that July and December 2020 levy payments to the District could be up to 15% less than planned due to the projected economic impact of the COVID-19 pandemic. In January 2020, we had planned to restore some service reductions implemented in 2017. In April 2020, we revised our plans to preserve our current cash reserves to insulate the District from negative economic impacts in 2020, 2021, and thereafter.

- We cancelled all planned partial service restorations except increased cattail mosquito treatments, froze regular fulltime staff hiring, and postponed certain large capital purchases such as scheduled replacement vehicles
- We did not increase the 2021 budget and levy over 2020 levels
- Social distancing restricted us to one employee per vehicle – consequently we hired 16% fewer seasonal technicians (about 32 seasonal employees) than planned in 2020

2020 outcome and our 2021 responses:

- We successfully limited 2020 expenditures to $14,353,143 in response to an expected 10-15% deficit levy receipts (this deficit largely did not happen in 2020)
- In January 2021, we chose to restore about one third of services cut in 2017 (originally planned in January 2020) because our financial situation supported these service restorations
- In December 2021, we approved a 2022 levy of $19,038,676 which is a 2% increase over 2020 and 2021 ($18,665,369) to support additional service restorations in 2022

Program Results 2021 has been one of the driest years since 1989. Adult mosquito abundance was very low overall. Larval and adult control were both were lower. Limitations due to COVID-19 that began in 2020, including hiring fewer seasonal employees, continued through 2021 (Table 4.1). The dry conditions mitigated service delivery impacts.

Table 4.1 Number of acres treated and number of seasonal inspectors 2016-2021

	2016	2017	2018	2019	2020	2021
Acres larval control	304,682	193,890	187,727	212,172	194,911	150,299
Acres adult control	82,967	42,012	38,479	22,325	6,450	2,537
Seasonal technicians	238	234	229	229	184	187

The dry conditions and resultant lower service demands in 2021 reduced our expenditures significantly below our 2021 budget. This, along with the increase in our 2022 levy and savings achieved in 2020 in anticipation of a significant levy deficit that largely did not occur, provides the District with the financial resources to restore more services in 2022 including all services cut in 2017. We also will have sufficient reserves to afford at least one high service demand year similar to 2014-2016 without depleting our reserves below the minimum level required to support District cash flow needs.

Larval Mosquito Control

Thresholds and Control Strategy Larval surveillance occurs prior to treatments, and control materials are applied when established treatment thresholds are met, as appropriate. Ground treatments and cattail site treatments are based on presence/absence criteria. For treatments by air, larval numbers must meet treatment thresholds. Table 4.2 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 2021

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

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

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

Control for a season begins in the fall of the previous year when we survey cattail sites for larvae of the cattail mosquito, *Cq. perturbans*. Some sites are treated with VectoLex® (*Bacillus sphaericus*) then to eliminate larvae before they overwinter. Some sites where *Cq. perturbans* larvae are limited to holes in cattail mats are treated with Altosid® briquets (methoprene) in February when the wetlands are still frozen. Other sites with cattail mosquito larvae present are treated with controlled release methoprene products (such as Altosid® pellets and Altosid® P35) by air or ground starting in late May to prevent adult emergence (usually peaking around July 4). Surveillance and control for the next season begins again in the fall (numbers reflected in 2020 control material use table).

Spring *Aedes* tend to be long-lived, 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 per 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® pellets, Altosid® P35, MetaLarv® S-PT) were applied in mid-May with a second in mid-June and a third in mid-July.

Season Overview In 2021, expanded larval spring *Aedes* surveillance in P1 and P2 areas with higher past adult abundance was limited because of dry conditions. Staff detected the first spring *Aedes* larvae on March 18, two days later than in 2020 (March 16), 18 days earlier than 2019 (April 5), and 37 days earlier than in 2018 (April 24). Aerial *Bti* treatments to control the spring *Aedes* brood began on April 22, fourteen days earlier than in 2020 (May 6), ten days earlier than in 2019 (May 2), and eighteen days earlier than in 2018 (May 10). The mosquito species composition switched to primarily *Ae. vexans* (summer floodwater) in early-May; the summer *Aedes* larval threshold was used beginning on May 5. In addition to the spring *Aedes* brood, there were two large and six small-medium broods of summer floodwater species (a typical season has four large broods).

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 2020 and 2021 (research tests not included)

	2021		2020	
Habitat and material used	Amount used	Acres treated	Amount used	Acres treated
Wetlands and structures				
Altosid® briquets (cases)	175.67	141	228.33	180
Altosid® pellets (lb)	0.38	0.16	1,826.02	729
Altosid® P35 (lb)	73,104.78	26,511	72,890.39	26,784
MetaLarv® S-PT (lb)	55,643.88	19,431	54,195.22	18,408
Natular® G30 (lb)	100,679.52	19,968	44,465.35	8,946
VectoLex® FG (lb)	74,246.17	5,255	27,430.76	1,858
VectoBac® G (lb)	396,881.97	78,992	676,175.40	138,006
Total wetland and structures		150,299		194,911
	Amount used	No. CB treatments	Amount used	No. CB treatments
Catch basins				
Altosid® briquets (cases)	1.92	414	2.14	470
Altosid® pellets (lb)	105.62	13,550	2,107.79	264,399
Altosid® P35 (lb)	2,188.50	270,810	98.47	11,648
Total catch basin treatments		284,774		276,517

Aerial pre-hatch treatments (Natular® G30, Altosid® P35) to control floodwater *Aedes* were applied in mid-May and mid-June. The majority of aerial treatments to control cattail mosquitoes using MetaLarv® S-PT and Altosid® P35 were applied the last seven days of May and the first three days of June (Figure 4.2); VectoLex® FG was applied September 22-23 to control the overwintering larval cattail mosquito population. Altosid® pellet use was much reduced in 2021 because we replaced it with Altosid® P35. We can apply Altosid® P35 at a lower dosage aerially than Altosid® pellets which enabled us to treat more acres because the per pound cost of Altosid® pellets and Altosid® P35 is similar. VectoLex® FG use (September aerial cattail site treatments) was higher in 2021 (Table 4.3), because these September 2021 cattail treatments cover part of the spring 2022 cattail treatments and are part of our plan to restore all services in 2022.

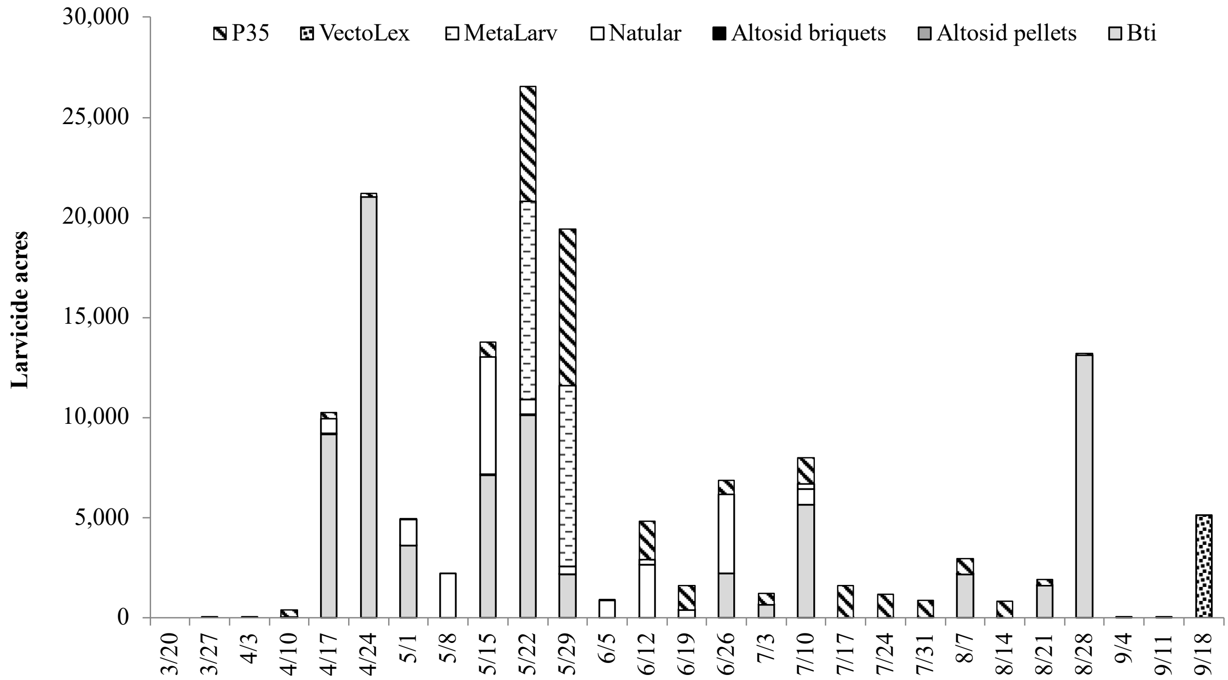


Figure 4.2 Acres treated with larvicide each week (March – September 2021). Date represents start date of week.

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

Cattail Mosquito Control Reduction Evaluation In 2018 through 2021, some control materials were shifted to cattail treatments to maximize treatment in P1. Cattail mosquito larvicide treatments in P2 largely were not applied in 2017 as part of a strategy to reduce expenditures. Relatively limited treatments were resumed in a few local areas within P2 in 2020 and 2021. Larval surveillance in late 2017 detected more sites containing cattail mosquito larvae in P1 than could be treated in spring 2018 with available resources. A similar number of acres containing cattail mosquito larvae were detected in late 2018. In 2018, larvicides were shifted from floodwater pre-hatch to treat more cattail sites, but available resources still were insufficient. All available resources were used in P1 in 2019. In 2020 and 2021, acreage requiring treatment was a bit lower in P1 which enabled us to treat a relatively small amount of P2, mainly a few areas near P1.

Three years (2014-2016) of high precipitation flooded many acres of cattail sites. Adult mosquito surveillance documented a large increase in adult cattail mosquitoes throughout the District in 2017 (see Chapter 1 for details); abundance decreased in 2018 suggesting that drier conditions in in 2018 through 2021 reduced water levels (and *Cq. perturbans* larval habitat) in many cattail sites. We compared adult cattail mosquito abundance in groups of CO_2 traps in P1 (cattail larvicide treatments maintained in 2016-2021) and P2 (limited cattail larvicide treatments completed in 2016, largely curtailed in 2017-2021) in Washington and Hennepin counties (Figure 4.3). Abundance in traps located in Linwood Township in Anoka County (no cattail mosquito control in 2016-2021) served as a reference (Figure 4.3).

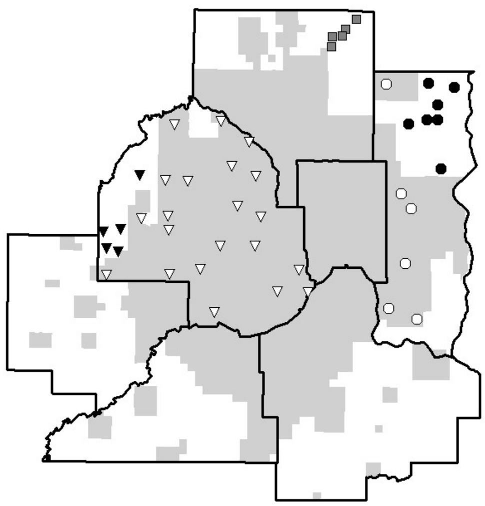


Figure 4.3 Location of CO_2 traps in Hennepin County (P1 white triangles, P2 black triangles), Washington County (P1 white circles, P2 black circles), and Anoka County (Linwood Township) (gray squares). P1 is shaded light gray.

Adult *Cq. perturbans* abundance as measured by CO_2 trap captures in 2016-2021 documented a large increase in 2017 throughout the District; abundance was more variable but lower in 2018-2020 and lowest in 2021 (Table 4.4). In 2016, 2017, 2018, 2019, 2020, and 2021, abundance was lower in P1 than in P2 in Hennepin and Washington counties (Table 4.4) suggesting that widespread larval control is lowering adult *Cq. perturbans* abundance in P1. The change in adult *Cq. perturbans* abundance each year was less variable in P1 suggesting that widespread larval control effectively suppressed *Cq. perturbans* abundance in 2016 through 2021. The environmental impact of high precipitation in 2014, 2015, and 2016 and lower overall precipitation in 2017 through 2021 seems to have more strongly affected *Cq. perturbans* abundance in P2. In 2016 through 2021, a much larger proportion of cattail mosquito production acreage in P1 was treated with larvicide compared to P2. When environmental conditions support high larval *Cq. perturbans* abundance, a greater proportion of acreage probably will require wide-scale larval control to more significantly decrease adult *Cq. perturbans* abundance.

Table 4.4 Adult *Coquillettidia perturbans* mean abundance in Monday Night Network CO_2 trap annual collections (2016-2021) in five groups of CO_2 traps [mean (± 1 SE)]; P1 and P2 are priority treatment zones, n=number of CO_2 traps, F=full, N=no control, and L=limited control is the control status

	Hennepin Co.		Washington Co.		Anoka Co. Linwood Twp.
	P1	P2	P1	P2	P2
Year	(n=21)	(n=5)	(n=6)	(n=7)	(n=5)
2016	19.3 (±4.6) F	42.0 (±15.4) L	30.6 (±11.4) F	161.1 (±26.8) L	325.1 (±67.5) N
2017	57.8 (±12.7) F	158.7 (±57.1) N	123.5 (±81.9) F	424.8 (±76.7) N	750.2 (±164.1) N
2018	15.7 (±4.7) F	93.6 (±34.9) L	32.4 (±21.2) F	174.9 (±48.0) L	257.9 (±77.3) N
2019	18.5 (±5.3) F	257.3 (±200.9) N	47.2 (±27.8) F	197.5 (±53.6) N	210.0 (±48.0) N
2020	50.3 (±11.6) F	185.2 (±69.3) N	48.8 (±13.9) F	355.5 (±66.1) N	297.0 (±64.9) N
2021	14.8 (±7.9) F	27.3 (±11.2) L	25.5 (±8.7) F	133.4 (±39.6) N	72.3 (±28.5) N

Coquillettidia perturbans surveillance for 2022 (completed in August–October 2021) detected lower abundance of this species as compared to 2021. Thus, we expect to need to treat fewer acres in P1 in 2022 compared to 2021, potentially enabling us to increase treatments in P2.

Spring *Aedes* Control Strategy Larval surveillance for spring *Aedes* was first expanded in 2018 to potentially shift some spring larvicide treatments into P2 to expand the area within the District that received larval control targeting suspected vectors of Jamestown Canyon virus. In 2021, 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 2021, we treated about as many acres for spring *Aedes* in P2 as in 2018 and total acreage treated in 2021 was comparable to 2019 (Table 4.5).

Table 4.5 Aerial *Bti* treatment-acres to control spring *Aedes* in P1 and P2 in 2017, 2018, 2019, 2020, and 2021

	Number of acres treated by year				
Priority area	2017	2018	2019	2020	2021
P1	26,204.57	18,044.52	31,146.39	18,304.36	28,008.30
P2	11.86	2,785.85	874.58	0.00	2,676.21
Total	26,216.43	20,830.37	32,020.97	18,304.36	30,684.51

Spring *Aedes* Control Strategy Evaluation The five groups of CO_2 traps used to compare *Cq. perturbans* abundance also were used to compare spring *Aedes* abundance relative to treatments in 2016-2021. Hennepin P1 and Washington P1 are areas where aerial *Bti* treatments targeting spring *Aedes* were completed from 2016-2021. Limited aerial *Bti* treatments were conducted in Hennepin and Washington P2 in 2016; these treatments were not made in 2017, limited treatments were completed in 2018, 2019 and 2021. No treatments in P2 were completed in 2020. No significant aerial *Bti* treatments targeting spring *Aedes* were completed from 2016-2021 in Linwood Twp. (Anoka County).

Low and variable numbers of adult spring *Aedes* were captured by CO_2 traps which made evaluating change challenging (Table 4.6). Spring *Aedes* abundance in 2016 through 2021 in

Hennepin P1 and Washington P1 was essentially equal for all six years; mean abundance each year differed by less than yearly variability (1 SE). Spring *Aedes* abundance was higher in 2019 in Hennepin P1 and Washington P1 but still within variability limits. Yearly spring *Aedes* abundance in Hennepin P2 and Washington P2 was much more variable. Abundance in P2 appeared higher in 2019 than in 2016, 2017, 2020, and 2021, especially in Washington County, although variance also was much higher in 2019. Spring *Aedes* abundance in Linwood Township was higher each year than in Hennepin P1 and Washington P1 and similar to Washington P2 in all years after 2017 except 2021 when half as many were collected in Washington P2 (Table 4.6). The less variable spring *Aedes* abundance in Hennepin P1 and Washington P1 in all six years suggests that widespread larval control is effectively suppressing spring *Aedes*.

Table 4.6 Adult spring *Aedes* mean abundance in Monday Night Surveillance CO_2 trap annual collections (2016-2021) in five groups of CO_2 traps [mean (± 1 SE)]. P1 and P2 are priority treatment zones, n=number of CO_2 traps, F=full, N=no control, and L=limited control is the control status

	Hennepin County		Washington County		Anoka Co. Linwood Twp.
Year	P1 (n=21)	P2 (n=5)	P1 (n=6)	P2 (n=7)	P2 (n=5)
2016	0.8 (±0.5) F	3.7 (±1.8) L	0.9 (±0.3) F	2.6 (±0.9) N	6.1 (±0.6) N
2017	1.0 (±0.8) F	1.5 (±0.8) N	0.4 (±0.2) F	8.5 (±5.5) N	17.6 (±4.9) N
2018	1.2 (±0.7) F	7.6 (±3.0) L	1.6 (±0.6) F	22.3 (±9.6) L	37.2 (±10.6) N
2019	2.9 (±1.3) F	13.6 (±7.5) L	2.8 (±0.9) F	38.0 (±15.1) L	22.7 (±4.5) N
2020	0.9 (±0.4) F	2.1 (±0.8) N	1.2 (±0.6) F	18.1 (±4.7) N	14.3 (±2.3) N
2021	0.9 (±0.3) F	2.8 (±2.1) L	2.6 (±1.0) F	9.7 (±2.3) L	17.9 (±4.6) N

Adult Mosquito Control

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

Table 4.7 Threshold levels by sampling method for important nuisance and vector species. *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*	130		
*Culex*4***	2004	1	5	1**	5
Ae. japonicus	2009	1	1	1	1
Cs. melanura	2012		5	5	

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

Season Overview In 2021, adult mosquito levels were very low all season. Above-threshold abundance peaked in very early June; vectors were more abundant throughout the season (Figure 4.4). In 2021, MMCD applied 3,913 fewer acres worth of adulticides than in 2020 because adult mosquito abundance was low (Table 4.8, Appendix E). Adult mosquito control was low all season with its greatest peak in late August primarily in response the vector mosquitoes (Figure 4.4). The decrease of adult control at the end of August was primarily due to cool weather.

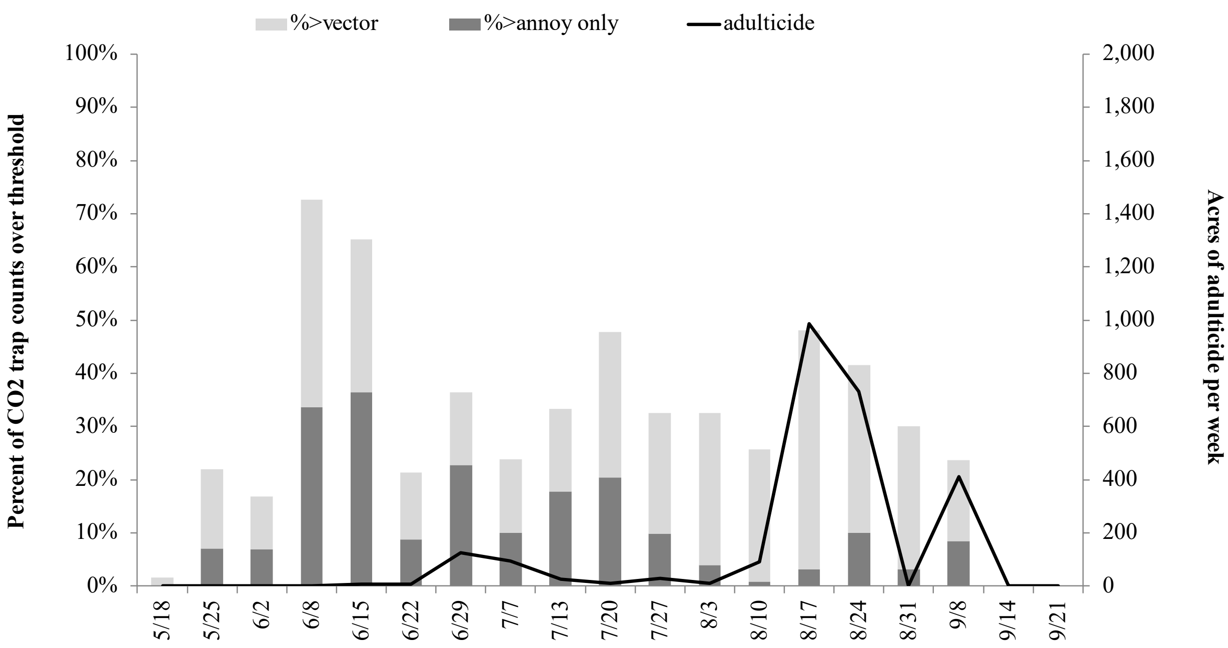


Figure 4.4 Percent of Monday CO_2 trap locations with counts over threshold compared with acres of adulticides applied in 2021 (solid line). Dark bars indicate the percentage of traps meeting annoyance mosquito thresholds and lighter bars represent the percentage of traps meeting the vector thresholds (*Culex*4, *Ae. triseriatus*, *Ae. japonicus*, *Cs. melanura*) on each sampling date. Date is day of CO_2 trap pick up.

Table 4.8 Comparison of adult control material usage in 2020 and 2021

	2021		2020	
Material	Gallons used	Acres treated	Gallons used	Acres treated
Permethrin	22.15	113	306.56	1,742
Sumithrin*	6.03	257	13.74	584
Etofenprox*	25.38	2,166	51.62	4,124
Total		2,537		6,450

* Products labeled for use in agricultural areas

References

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

2022 Plans for Mosquito Control Services

Integrated Mosquito Management Program

In 2022, MMCD will review all aspects of its integrated mosquito management program to ensure that budgetary resources are being used as effectively as possible with the goal of maximizing mosquito control services per budget dollar, maximizing mosquito control services given available resources, restoring all services cut in 2017, and complying with all NPDES-related permit requirements. Further discussion regarding the Clean Water Act's NPDES permit requirements is in Chapter 7. Our control materials budget in 2022 will remain the same as in 2021.

Larval Control

End of Temporary Measures to Decrease Expenditures In 2022 (if economic conditions permit), we plan to restore all service reductions first implemented in 2017. Because of a slight overall decrease of acreage meeting larval threshold for the cattail mosquito treatment observed by larval surveillance District-wide in late 2021, we plan to allocate more resources for cattail mosquito control in P2 in 2022. We anticipate no COVID-19 related delay in hiring seasonal inspectors in 2022 meaning we should be able to increase earlier season spring *Aedes* surveillance and larval control.

Floodwater Mosquitoes The primary control material will again be *Bti* corn cob granules. Larvicide needs in 2022, mainly *Bti* (VectoBac® G), Altosid® P35, Natular® G30, and MetaLarv® S-PT, are expected to be similar to the five-year average larvicide usage (188,888 acres). In 2022, we plan to continue the spring *Aedes* larval threshold used in 2021 (1 per dip in both P1 and P2) and consider expanding P2 treatments as resources allow to reduce potential JCV vectors in areas where human populations are present. We plan to treat spring *Aedes* sites with *Bti* at 5 lb/acre and maintain this *Bti* dosage when we switch to the summer *Aedes* threshold. As in previous years, to minimize shortfalls, control material use may be more strictly apportioned during the second half of the season, depending upon the amount of the season remaining and control material supplies. Regardless of annoyance levels, MMCD will maintain sufficient resources to protect the public from potential disease risk.

Staff will treat ground sites with Natular® G30, methoprene products (Altosid® P35, Altosid® briquets, MetaLarv® S-PT), or *Bti* (VectoBac® G). 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 2021 (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.

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). New adult treatment thresholds for *Ae. japonicus* will be 2 in all sampling methods.

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 2022, control of *Cq. perturbans* will use a strategy similar to that employed in 2021. MMCD will focus control activities on the most productive cattail marshes near human population centers. Altosid® briquet applications will start in early March to frozen sites (e.g., floating bogs, deep water cattail sites, remotely located sites). Largely because of control material prices, a greater proportion of acres will be treated with Altosid® P35 and MetaLarv® S-PT to minimize per-acre treatment costs. Beginning in late May, staff will apply Altosid® P35 (3 lb/acre) and MetaLarv® S-PT (3 lb/acre) aerially and by ground. Staff will complete late summer VectoLex® FG applications (15 lb/acre), based upon site inspections completed between mid-August and mid-September.

Adult Mosquito Control

Staff will continue to review MMCD's adulticide program to ensure effective resource use and minimize possible non-target effects. Adulticide requirements in 2022 are expected to be similar to the five-year average adulticide usage (22,100 acres). We will continue to focus efforts where there is potential disease risk, as well as provide service in high-use park and recreation areas and for public functions and respond to areas where high mosquito numbers are affecting citizens.

Additional plans are:

- to use Anvil® (sumithrin) and Zenivex® (etofenprox) as needed to respond to elevated levels of adult mosquitoes as needed
- to use Anvil® and Zenivex® as needed to control WNV vectors including in agricultural areas because current labels now allow applications in these areas
- to evaluate possible adulticide use in response to *Ae. japonicus* and *Cs. melanura*
- to ensure all employees who may apply adulticides have passed applicator certification testing for both restricted and non-restricted use products
- review monarch ecological information available from groups including Monarch Joint Venture to account for seasonal events such the monarch migration in late summer when planning adult mosquito control

Chapter 5 Black Fly Control

2021 Highlights

- Made 58 small stream treatments with *Bti* when the *Simulium venustum* or *Simulium tuberosum* larval populations met the treatment threshold; a total of 25.8 gallons of *Bti* were used
- 2021 was the first year that *Simulium tuberosum* larval populations were treated
- Made 52 *Bti* treatments on the large rivers when the larval population of the target species met the treatment threshold; a total of 1,146 gallons of *Bti* was used
- Monitored adult populations using overhead net sweeps and CO_2 traps; the average black fly/overhead sweep count was 0.18
- Completed the report on the 2019 Mississippi River non-target invertebrate monitoring study

2022 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
- Collect samples for the Mississippi River non-target study

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 191 small stream and 29 large river sites using standardized sampling techniques during the spring and summer. Liquid *Bti* is applied to sites when the target species reach treatment thresholds 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. The MNDNR permitted *Bti* treatment for *S. tuberosum* at 25 sites on 5 small streams in the areas where it has become abundant. 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.

2021 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.

Sampling to monitor larval populations of *S. venustum* and *S. tuberosum* for treatment thresholds at the MNDNR-permitted

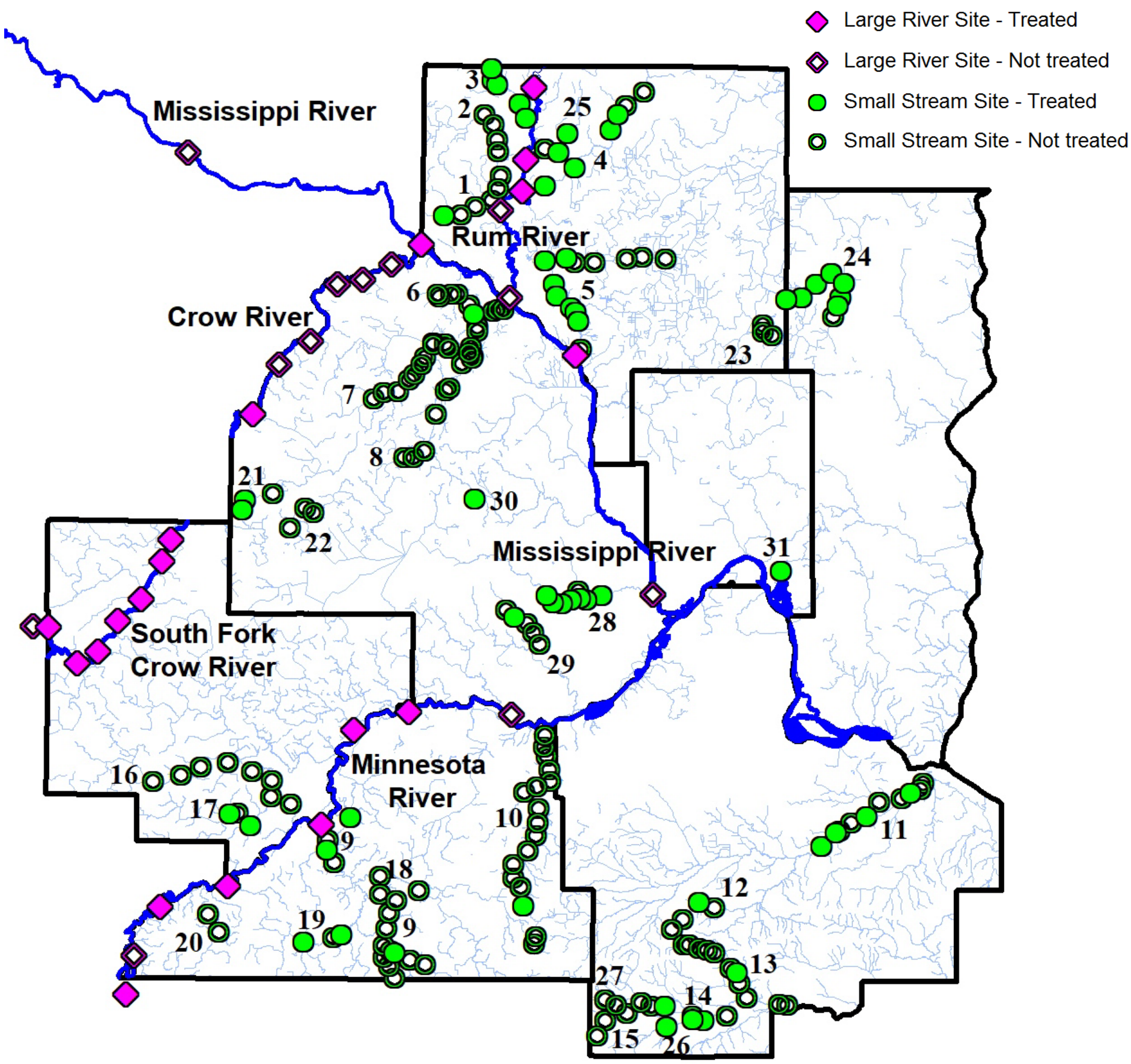


Figure 5.1 Large river and small stream black fly larval monitoring and treatment locations, 2021.

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* populations. In 2021, sites were added as *S. tuberosum* treatment locations. The numbers on the map refer to the small stream names listed below:

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

small stream sites were conducted between late April and mid-June using MMCD's standard sampling technique. A total of 295 monitoring samples were collected. The treatment threshold was 100 larvae per sample for both species. Forty-three sites on sixteen small streams met the treatment threshold for *S. venustum* and were treated once with VectoBac® 12AS *Bti*. The treatment threshold for *S. venustum* was also met three times in late April on the Rum River and it was treated with 37.0 gallons of *Bti*. Treatment for *S. venustum* in the Rum River is permitted by MNDNR when the treatment threshold is met. Data for *S. venustum* monitoring and *Bti* treatments on the Rum River are tallied with the large river totals. Fourteen sites on five streams met the treatment threshold for *S. tuberosum*. Minnehaha Creek site 229 met the treatment threshold for S. *tuberosum* twice and was treated both times. A total of 25.8 gallons of *Bti* was applied to the small streams in 2021. In comparison, the average amount of *Bti* used to treat small stream sites annually during 1996-2020 was 28.4 gallons (Table 5.1).

Table 5.1 Summary of *Bti* treatments for black fly control by the MMCD in 2021 versus long-term average

	2021			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	57	58	25.8	44.3	44.3	28.4
Large River						
Mississippi	2	2	146.0	2.1	10.7	1,172.7
Crow	1	2	15.3	2.2	5.2	96.7
S. Fork Crow	7	16	53.7	5.6	11.9	107.6
Minnesota	6	13	846.0	6.0	16.3	1,753.7
Rum	3	19	85.0	3.3	19.6	146.0
Large River Totals	19	52	1146.0	19.2	59.4	3,238.0

[1] The Mississippi, Crow, Minnesota, Rum, and small stream averages are from 1996-2020. The South Fork Crow average is from 2005-2020.

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 *Simulium johannseni* larvae occur primarily in the Crow, South Fork Crow, and Minnesota rivers. These species are most abundant in May and June, although *S. 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.

The large river black fly larval populations were monitored weekly between May and mid-September using artificial substrate samplers (Mylar tapes) at the 29 sites permitted by the MNDNR on the Rum, Mississippi, Crow, South Fork Crow, and Minnesota rivers in 2021. 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 432 larval monitoring samples were collected from the large river sites in 2021. The treatment threshold was met in 52 samples from 19 of the permitted sites; the associated sites were treated with a total of 1,146 gallons of VectoBac® 12AS *Bti* (Table 5.1). The average amount of *Bti* used annually for the large river treatments between 1996 and 2020 was 3,238 gallons. The amount of *Bti* used in 2021 was 2,092 gallons less than the long-term average. The average number of treatments done annually from 1996 to 2020 was 59.4 at 19.2 sites (Table 5.1).

Stream flow was below average during the black fly season on each of the five large rivers that the MMCD targets for black fly control due to the severe drought that occurred throughout most of Minnesota in 2021. The average monthly flows between April and September on the Rum, Mississippi, Minnesota, Crow, and South Fork Crow rivers were 38%, 40%, 53%, 62%, and 68% below the long-term average, respectively. Due to the low flows, substantially less *Bti* was used for control of black flies on the large rivers in 2021 compared to the long-term average. This was for two primary reasons. First, fewer treatments were done because treatment thresholds were not met as often because of lower black fly production, particularly for *S. luggeri* and *S. meridionale* in the Mississippi and Minnesota rivers. Secondly, because the amount of *Bti* that is needed to achieve the prescribed dose of 25 ppm for a treatment is directly proportional to stream flow, less *Bti* was used due to the drought-level flows (Table 5.1).

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 2021. Post-treatment mortality was 96% on the Minnesota River, 96% on the Rum River, 94% on the Crow River, and 85% on the South Fork Crow River. Check-backs were not done following the treatments on the Mississippi River at the Dayton and Coon Rapids Dam sites, because it was deemed unsafe to wade into the rapids to get to the check-back sample locations. These sites are normally accessed by boat for safety reasons, but due to the low flows that was not feasible.

Adult Population Sampling

Daytime Sweep Net Collections The adult black fly population was monitored at 54 standard stations (Figure 5.2) using the District's black fly over-head net sweep technique that was established in 1984. 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 2021 was 0.18/sweep (± 1.17 SD). In comparison, the average of all species captured in net sweeps from 1996 (the start of operational *Bti* treatments) to 2020 was 1.28/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).

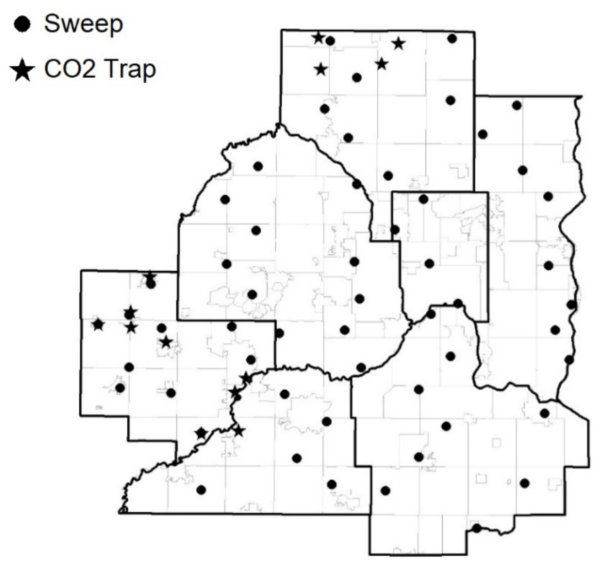


Figure 5.2 Standard overhead sweep net sampling locations (n=54) and CO_2 trap (n=13) sampling locations, 2021.

The county with the highest number of total black flies captured in the sweep net monitoring samples was Hennepin County, where a mean of 0.38 (± 1.92 SD) per sample for all species was recorded. The county with the second-highest sweep net count for total black flies was Dakota County, where the mean was 0.36 (± 1.80 SD) per sample. Anoka County was the third-highest county for the net sweep count of total black flies with a mean of 0.14 (± 0.46 SD) per sample.

The most abundant black fly species collected in the overhead sweep net samples in 2021 was *S. luggeri*, comprising 37.0% of the total black fly adults captured with an average of 0.07 (± 0.66 SD) per sample. The second most abundant black fly species captured were *S. vittatum,* comprising 27.1% of the total with an average of 0.05 (± 0.56 SD) specimens per sample. The third most abundant black fly species captured was *S. meridionale,* comprising 20.8% of the total with an average of 0.04 (± 0.30 SD) per sample. The fourth most abundant black fly species captured were *S. venustum,* comprising 5.7% of the total with an average of 0.01 (± 0.11 SD) specimens per sample. *Simulium tuberosum* was the fifth most abundant black fly species collected in the net sweep samples in 2021. They comprised 4.7% of the total with a mean of 0.01 (± 0.22 SD).

Simulium luggeri was most numerous in Hennepin and Anoka County sweep samples. The mean number of *S. luggeri* per sample was 0.23 (± 1.35 SD) in Hennepin County and 0.09 (± 0.37 SD) in Anoka County. *Simulium meridionale* was most abundant in the Dakota County samples, with a mean of 0.11 (± 0.63 SD) per sample. Carver County had the second-highest number *S. meridionale* with a mean of 0.05 (± 0.25 SD). *Simulium venustum* was most abundant in the Anoka County samples, with a mean of 0.04 (± 0.24 SD) per sample. *Simulium tuberosum* was most abundant in Hennepin County, with a mean of 0.04 (± 0.48 SD) per sample.

Table 5.2 Mean number of black fly adults captured in over-head net sweeps taken at standard sampling locations between mid-May and mid-September; samples were taken once weekly beginning in 2004 and twice weekly in previous years

Large river *Bti* treatment status[1,2,3,4]	Time Period	Mean ± SD			
		All species[5]	*Simulium luggeri*	*Simulium johannseni*	*Simulium meridionale*
No treatments	1984-1986	14.80 ± 3.04	13.11 ± 3.45	0.24 ± 0.39	1.25 ± 0.55
Experimental treatments	1987-1995	3.63 ± 2.00	3.16 ± 2.05	0.10 ± 0.12	0.29 ± 0.40
Operational treatments	1996-2020	1.28 ± 0.80	0.95 ± 0.76	0.01 ± 0.02	0.21 ± 0.27
	2021	0.18 ± 1.17	0.07 ± 0.66	0.00 ± 0.07	0.04 ± 0.30

[1]1988 was a severe drought year and limited black fly production occurred.

[2]The first operational treatments of the Mississippi River began in 1990 at the Coon Rapids Dam.

[3]1996 was the first year of operational treatments (treatment of all MNDNR-permitted sites) on the large rivers.

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

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

Black Fly-Specific CO_2 Trap Collections Adult black fly populations were monitored from mid-May through June in 2021 with CO_2 traps set twice weekly at four stations each in Scott and Anoka counties and five stations in Carver County (Figure 5.2). The adult black fly population at these stations have been monitored with CO_2 traps since 2004. Black flies captured in the CO_2 traps are preserved in alcohol.

A total of 12,952 black flies were captured in the CO_2 traps in 2021, which was the second-lowest number of black flies captured since CO_2 trap sampling began in 2004. The lowest number captured in the CO_2 traps was 10,123 in 2015 when drought-level flows occurred, particularly during the spring. The most abundant species collected in 2021 was *S. meridionale,* with a total of 9,648 specimens that comprised 74.5% of the total black flies collected in the CO_2 samples. *Simulium johannseni* was the second most abundant species collected, with a total of 1,866 specimens that comprised 14.4% of the total collection. The third most numerous species collected was *S. venustum* with a total of 1,245 specimens that comprised 9.6% of the total. A total of only 5 *S. tuberosum* and 61 *S. luggeri* were captured in 2021, comprising 0.04% and 0.47% of the total collection, respectively. Table 5.3 lists the mean number of *S. meridionale*, *S. johannseni,* and *S. venustum* captured in the CO_2 traps in Anoka, Scott, and Carver counties since the trapping program began in 2004.

Table 5.3 Mean number of adult *Simulium venustum*, *S. johannseni*, and *S. meridionale* captured in CO_2 traps set twice per week between May and mid-June in Anoka, Scott, and Carver counties, 2004-2021[a]

	S. venustum			*S. johannseni*			*S. meridionale*		
Year	Anoka	Scott	Carver	Anoka	Scott	Carver	Anoka	Scott	Carver
2004	0.89	2.25	0.25	5.11	0.17	32.93	14.09	0.65	327.29
2005	2.31	3.40	0.84	0.03	3.50	99.04	1.23	23.25	188.02
2006	22.80	3.38	1.82	0.75	38.07	98.75	0.75	10.50	107.53
2007	37.62	35.59	75.67	0.20	32.50	112.77	0.51	172.48	388.64
2008	13.84	228.93	169.63	0.13	20.18	95.63	0.68	75.03	359.02
2009	18.32	238.16	425.00	0.34	22.80	35.92	0.70	98.77	820.25
2010	21.75	44.60	77.00	0.03	6.18	219.38	0.05	256.90	271.08
2011	8.90	60.64	48.30	2.61	280.64	4,584.72[b]	0.93	311.55	268.28
2012	2.89	5.45	0.40	0.95	81.73	154.13	0.41	242.55	100.53
2013	14.61	3.09	1.44	1.18	4.88	14.03	0.00	111.45	322.43
2014	13.64	16.82	8.68	3.36	12.36	702.82	1.32	12.64	193.57
2015	9.83	1.14	0.43	0.37	35.17	12.43	0.17	23.31	161.30
2016	1.70	0.72	0.02	1.50	2.89	35.41	0.86	64.33	501.85
2017	7.48	2.56	1.42	6.17	6.86	71.08	1.00	38.94	298.54
2018	9.79	3.87	4.94	0.00	4.09	280.79	1.36	160.06	436.58
2019	6.89	6.72	0.48	0.53	2.43	3.70	2.36	11,347.24	3,318.10
2020	8.15	40.25	0.41	0.26	5.36	72.85	2.26	386.04	734.85
2021	5.24	13.61	0.61	0.11	0.89	22.53	0.65	83.78	53.08
SD	±16.80	±51.56	±2.58	±0.66	±3.18	±103.61	±1.66	±233.86	±131.64
No. Traps	4	4	5	4	4	5	4	4	5

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

Simulium tuberosum Small numbers of larvae and adult *S. tuberosum* have been found in larval and adult monitoring samples since the black fly program began in 1984, but until recently they have not been abundant enough to be considered a pest of humans. However, in recent years, the number of *S. tuberosum* in both larval and adult monitoring samples have increased, particularly in Hennepin County, and parts of Scott, Dakota, and Ramsey counties. Between 2011 and 2014, the percentage of *S. tuberosum* collected in District sweep net monitoring samples was less than 1% annually. However, since 2015 the percentage of *S. tuberosum* in the sweep net samples has ranged between 1.6 and 7.8% (Fig. 5.3). Coincident with this increase, the District started receiving large numbers of citizen complaints concerning biting black flies (locally called gnats) (Fig. 5.4).

Field investigations of citizen complaints about pestiferous black flies indicated that the species responsible was likely *S. tuberosum.* Interestingly, coincident with the outbreak of *S. tuberosum* in 2020 in southern Hennepin County, physicians at medical clinics in the vicinity of the outbreak experienced an increase in children presenting with diagnoses of multiple punctate lesions on the posterior neck/hairline region that were ultimately identified as black fly bites. The families of all patients confirmed black fly exposure on questioning by the clinicians. Along with the punctate lesions, the patients also exhibited a range of symptoms that included sentinel bleeding and mild edema with surrounding erythema in the days after the bite. One patient developed prominent cervical lymphadenopathy. Patient healing took one to two weeks (Mittelstet et al., 2021). Severe allergic reactions have been observed in humans in rare cases of black fly bites (Orange et al., 2004).

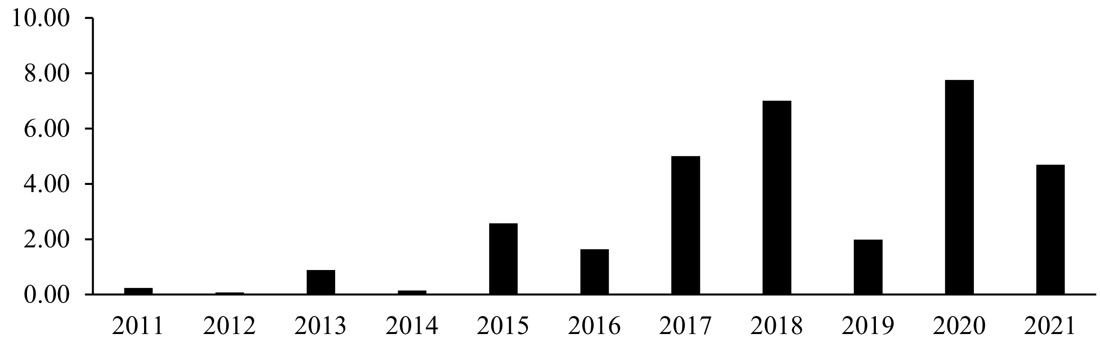


Figure 5.3. Percentage of *Simulium tuberosum* collected in the standard overhead net-sweep monitoring samples, 2011-2021.

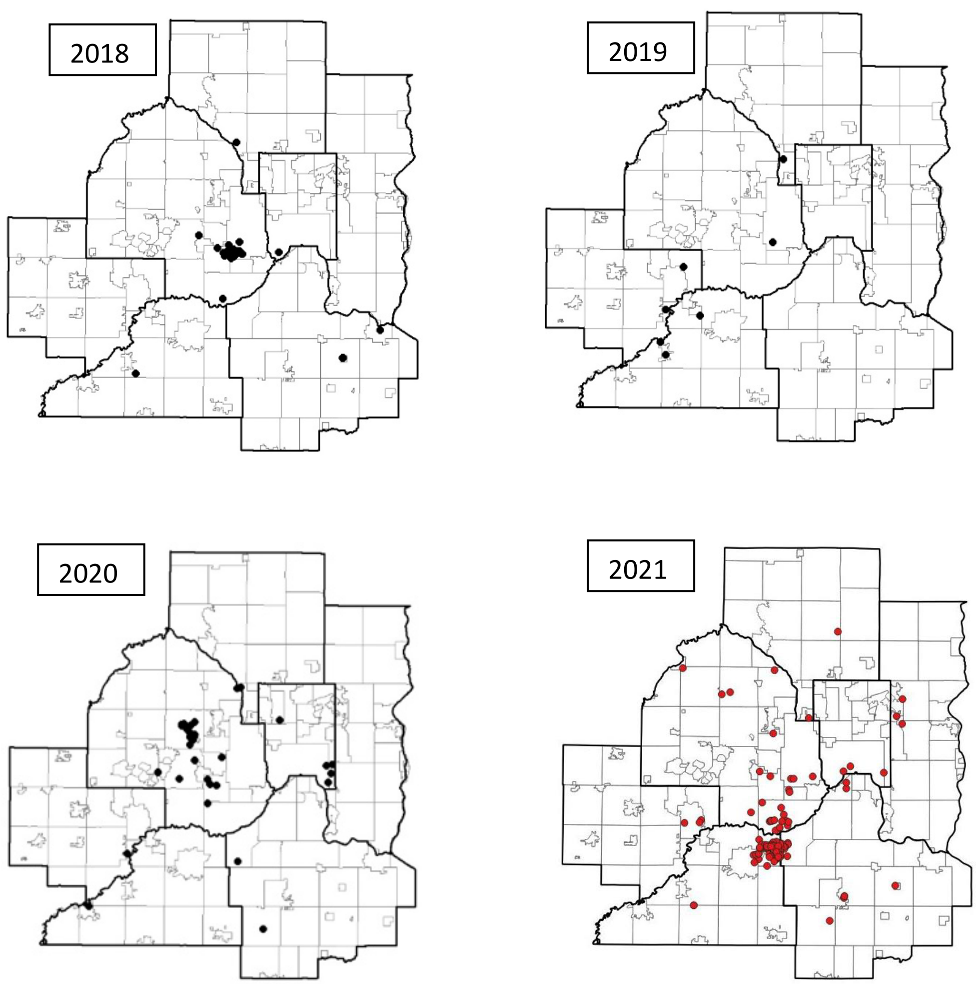


Figure 5.4 Black fly (biting gnats) annoyance customer call locations, 2018, 2019, 2020, and 2021.

In response to the outbreaks of *S. tuberosum*, the District requested and was granted an addendum to its 2021 small stream permit from the MNDNR for treatment of *S. tuberosum* at twenty-five sites on five small streams when the treatment threshold of 100 larvae per standard sample was reached. Each of the sites that was included on this treatment list was documented to have large populations of *S. tuberosum* larvae based on monitoring samples collected between 2018 and 2020. In 2021, 14 sites on five streams (Minnehaha, Nine Mile, Vermillion, Plymouth, and Battle creeks) met the treatment threshold for *S. tuberosum* and were treated with *Bti*.

Follow up investigations on the 2021 customer call clusters in Savage and southern Bloomington showed large populations of both larval and adult *S. tuberosum* in the area. The District plans to request additional sites in its 2022 black fly permit application to the MNDNR for *Bti* treatment on the streams where large larval populations of *S. tuberosum* were found in these two areas. The District will also continue to monitor larval and adult populations of *S. tuberosum* in 2022. Ongoing studies on the seasonal bionomics and ecology of *S. tuberosum* will also continue in 2022 to further enhance the District's understanding of the pest status of this species. Program staff will continue to keep the MNDNR informed of its findings on this issue.

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 2021. Because these traps are operated for mosquito surveillance, samples are not placed in ethyl alcohol making black fly species-level identification difficult. Results are represented geographically in Figure 5.4. The areas in dark gray and black represent the highest numbers collected, ranging from 250 to more than 500 per trap. Moderate levels of black flies were observed in May and early June in parts of Carver, Scott, and Dakota counties (Figure 5.5). The peak average number of black flies occurred on June 2 (Figure 5.6). The average number of black flies was below the 14-year average the entire season.

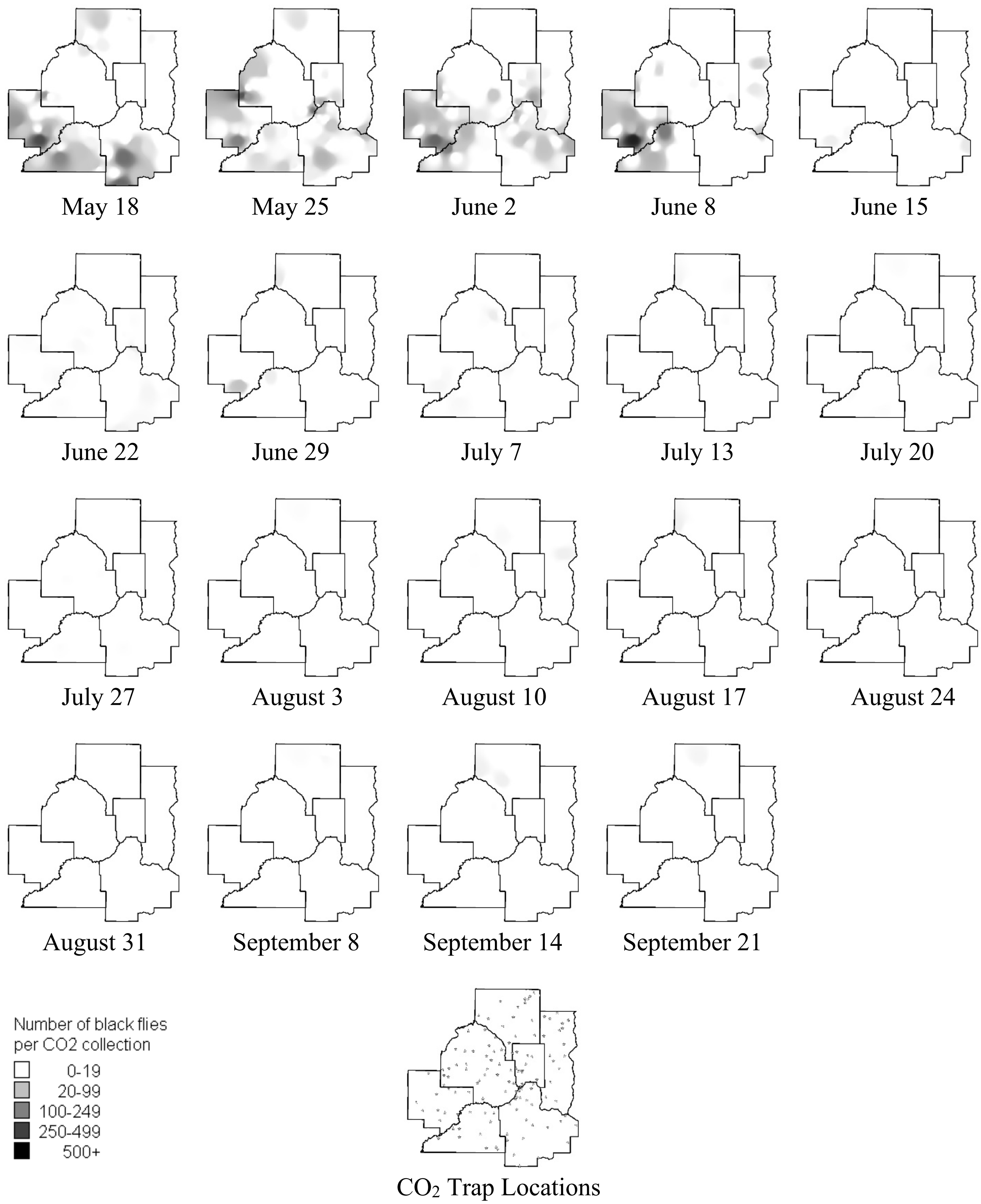


Figure 5.5 Number of black flies collected in mosquito surveillance District low (5 ft) and elevated (25 ft) CO_2 traps, 2021. The number of traps operated per night varied from 127-133. Inverse distance weighting was the algorithm used for shading of maps.

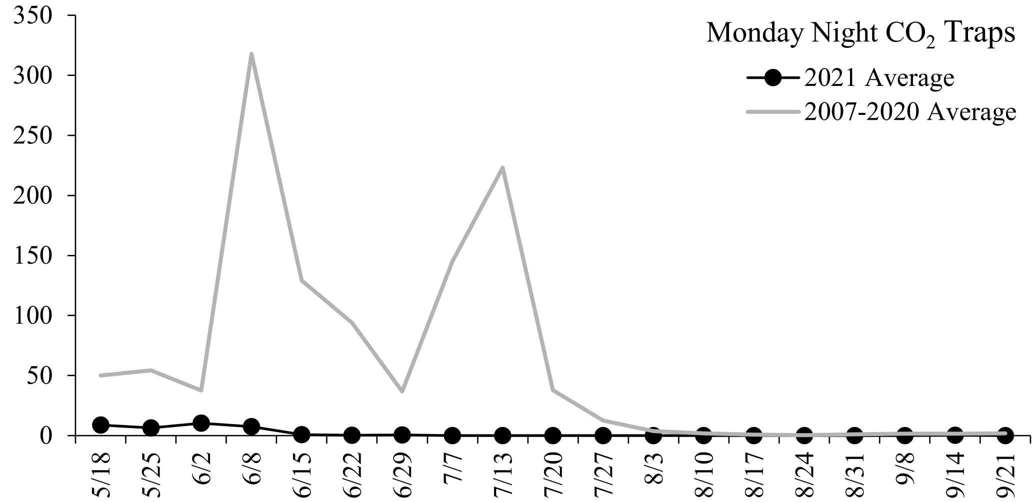


Figure 5.6 Average number of black flies per Monday Night Network CO_2 low trap, 2021 vs. 14-year average (2007-2020).

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 report on the Mississippi River monitoring samples collected in 2019 was submitted to the MDNR in July 2021. Results were consistent with those from the previous monitoring studies done by the MMCD since 1995 and indicated that there have been no large-scale changes 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 deployment of the Hester-Dendy multiplate macroinvertebrate samplers for the scheduled biennial non-target sampling study. The MMCD consulted with the MDNR about this situation, and it was mutually agreed to delay sampling until 2022. Samplers will be deployed starting in May 2022.

2022 Plans – Black Fly Program

2022 will be the 38th year of black fly control in the District. The primary goal in 2022 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 2022 black fly control permit application will be submitted to the MNDNR in February. The Mississippi River non-target monitoring samples will be collected using 7-plate multiplate samplers starting in May. Studies on the distribution, abundance, and ecology of immature and adult *S. tuberosum* will continue in order 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.

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Orange, J.S., L.A. Song, F.J. Twarog, and L.C. Schneider. 2004. A patient with severe black fly (Simuliidae) hypersensitivity referred for evaluation of suspected immunodeficiency. Ann. Allergy Asthmas Immunol. 92: 276–280.

Chapter 6 Product & Equipment Tests

2021 Highlights

- 5-lb/acre dosages of VectoBac® G *Bti* achieved good control of spring *Aedes* and *Aedes vexans* in air sites
- VectoLex® FG (20 g/cb) effectively controlled mosquito larvae in catch basins verifying 2019 and 2020 results
- VectoLex® WSP (10 g/WSP) (one or two WSP/cb) effectively controlled mosquito larvae in catch basins. Control was equal to VectoLex® FG (20 g/cb)

2022 Plans

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

Background

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

2021 Projects

Quality assurance processes focused on product evaluations, equipment, and waste reduction. Before being used operationally, all products must complete a certification process that consists of tests to demonstrate how to use the product to effectively control mosquitoes. The District conducted certification testing of one larvicide. Our goal is to determine that different larvicides can control two or more target mosquito species (i.e., nuisance or disease vector) in multiple control situations. These additional control materials provide MMCD with more operational tools.

Control Material Acceptance Testing

Larval Mosquito Control Products Warehouse staff collected random product samples from shipments received from manufacturers for active ingredient (AI) content analysis. MMCD contracts an independent testing laboratory, Legend Technical Services, to complete the AI analysis. Manufacturers provide the testing methodologies. The laboratory protocols used were CAP No. 311, "Procedures for the Analysis of S-Methoprene in Briquets and Premix", CAP No. 313, "Procedure for the Analysis of S-Methoprene in Sand Formulations", VBC Analytical Method: VBC-M07-001.1 Analytical Method for the Determination of (S)-Methoprene by High Performance Liquid Chromatography and Clarke Analytical Test Method SP-003 Revision #2 "HPLC Determination of Spinosad Content in Natular® G30 Granules".

The manufacturer's certificates of analysis at the time of manufacture for samples of all control materials shipped to MMCD in 2021 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), 2021

Product evaluated	No. samples analyzed	AI content: Label claim	AI content: Analysis average	SE
Altosid® XR-briquets	5	2.10%	2.20%	0.0148
Altosid® P35 granules	39	4.25%	4.22%	0.0132
MetaLarv® S-PT granules	10	4.25%	4.28%	0.0443
Natular® G30 granules	10	2.50%	2.45%	0.0643

Adult Mosquito Control Products MMCD requests certificates of AI analysis from the manufacturers to verify product AI levels at the time of manufacture. MMCD has incorporated AI analysis as part of a product evaluation procedure and will submit randomly selected samples of adulticide control materials to an independent laboratory for AI level verification. This process will assure that all adulticides (purchased, formulated, and/or stored) meet the necessary quality standards. 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 2021. Aerial *Bti* treatments to control the spring *Aedes* brood began on April 22, fourteen days earlier than in 2020 and ten days earlier than in 2019. All applications used the 5 lb/acre rate to conserve funds. In 2021, aerial *Bti* treatments averaged 84.8% control (Table 6.2), comparable to 88.0% in 2020, 85.9% control in 2019, 88.0% control in 2018, 84.5% control in 2017, 86.0% control in 2016, 83.7% control in 2015, and 90.4% control in 2014. Percent mortality was calculated by comparing pre- and post-treatment dip counts.

Table 6.2 Efficacy of aerial VectoBac® G applications (5 lb/acre) during the 2021 mosquito season (n = number of sites dipped)

Time period	Dosage rate	n	Mean mortality	±SE*
April 22 – August 31	5 lb/acre	324	84.8%	1.6%

*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 2021 was designed to evaluate how different segments of mosquito control programs can be modified to deliver more mosquito control services to a greater part of the District area using existing resources. Much testing has focused upon controlling multiple mosquito species including potential vectors. The reduced number of seasonal employees hired because of the COVID-19 pandemic limited the amount of research testing that could be completed in 2021.

Larval Control

VectoLex® FG and WSP in Catch Basins Operationally, we treat catch basins three or four times each season with Altosid® pellets or Altosid® P35 (both 3.5 g per catch basin) to control vector mosquitoes. VectoLex® contains a different active ingredient (*Bacillus sphaericus*) than Altosid® which should help with resistance management. In 2019 we tested Altosid® P35, Altosid® pellets, and VectoLex® FG in catch basins to verify that we could use all three products to effectively control vectors. Results indicated that all three products effectively controlled vectors for up to four weeks (see 2019 Operational Review and Plans for 2020 for details). We again tested VectoLex® FG at an operational dosage (20 g per catch basin) in 2020 and replicated the excellent results observed in 2019 (see 2020 Operational Review and Plans for 2021 for details). In 2021, we compared VectoLex® FG (20 g per catch basin) with VectoLex® WSP because the WSP formulation does not require the applicator to wear a N95 mask during treatment. We included treatments of one and two WSP per catch basins because each WSP contains 10 g of VectoLex®.

Four groups of catch basins were designated. All catch basins were in St. Paul, MN. Twenty catch basins were treated with VectoLex® FG (20 g per catch basin), twenty with VectoLex® WSP (1 WSP per catch basin) and twenty with VectoLex® WSP (2 WSP per catch basin). Each VectoLex® WSP contains 10 g. All VectoLex® FG and WSP treatments were applied on June 7, July 7, August 4, and September 3. Thirty untreated catch basins were monitored in the same manner as treated catch basins. Catch basins from each treatment group were inspected each week by MMCD staff, weather and workload permitting, from the week of larvicide application through September until the temperature dropped enough to inhibit oviposition by mosquitoes in catch basins. We collected and counted larvae and pupae from all catch basins.

The number of larvae (Figure 6.1) and pupae (Figure 6.2) collected from catch basins (untreated or treated with VectoLex® FG or VectoLex® WSP) each week varied during the sampling period. Overall, catch basins treated with VectoLex® FG or VectoLex® WSP contained fewer larvae and pupae than untreated catch basins (Table 6.3), although one might question the effectiveness of VectoLex® FG and VectoLex® WSP because larvae and pupae still are present on many sampling dates (Figure 6.1, 6.2). The much lower abundance of pupae in catch basins treated with VectoLex® FG or VectoLex® WSP suggested effective control (Table 6.3) because pupal abundance is the closest proxy for adult mosquito emergence that is readily available.

Table 6.3 Mean number of larvae (all instars) and pupae from untreated (control) and catch basins treated VectoLex® FG (20 g per catch basin), one or two VectoLex® WSP (10 g per WSP) (after June 7 treatment)

		Larvae per dip		Pupae per dip	
Material	No. inspections	Mean	SE*	Mean	SE*
VectoLex® FG	330	17.31	2.55	0.18	0.14
VectoLex® WSP (1)	327	14.11	1.90	0.10	0.06
VectoLex® WSP (2)	323	11.88	2.07	0.06	0.04
Control	410	56.58	3.96	3.44	0.85

*SE= standard error

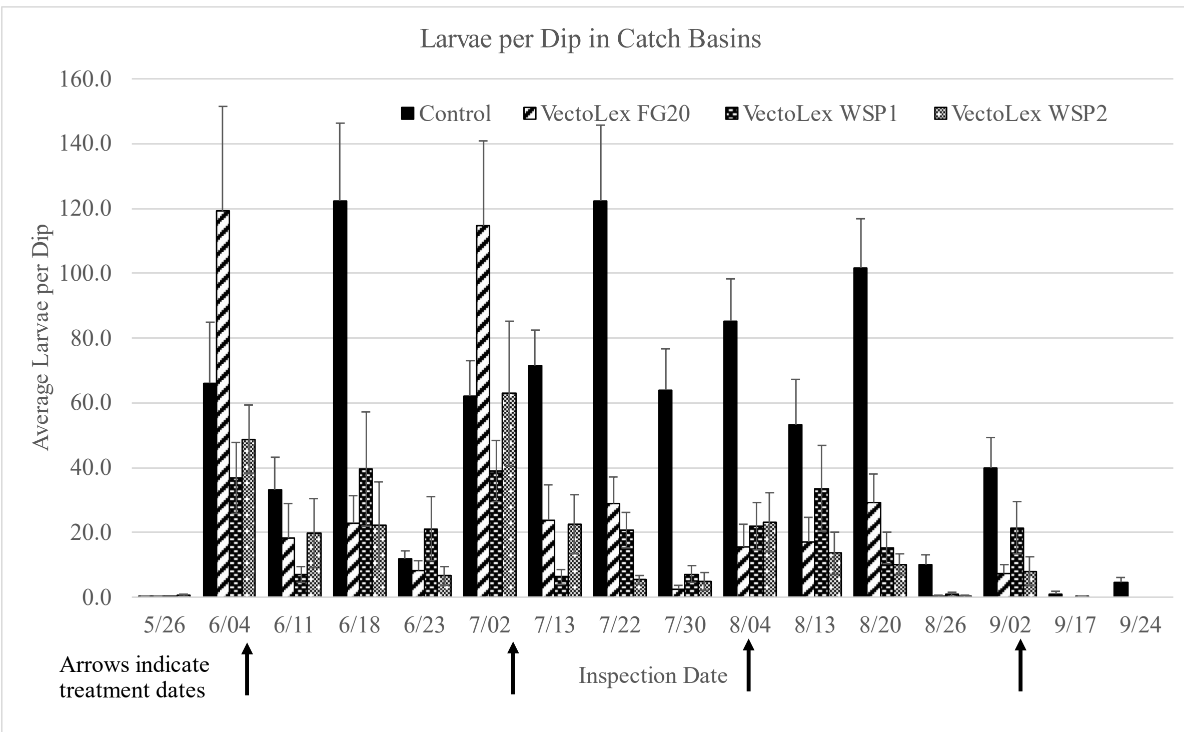


Figure 6.1 Mean number of larvae (all instars) from untreated (control) and catch basins treated with VectoLex® FG (20 g per catch basin), one or two VectoLex® WSP (10 g per WSP) on each sample date. Error bars equal one Standard Error. Arrows indicate VectoLex® FG and WSP treatment dates.

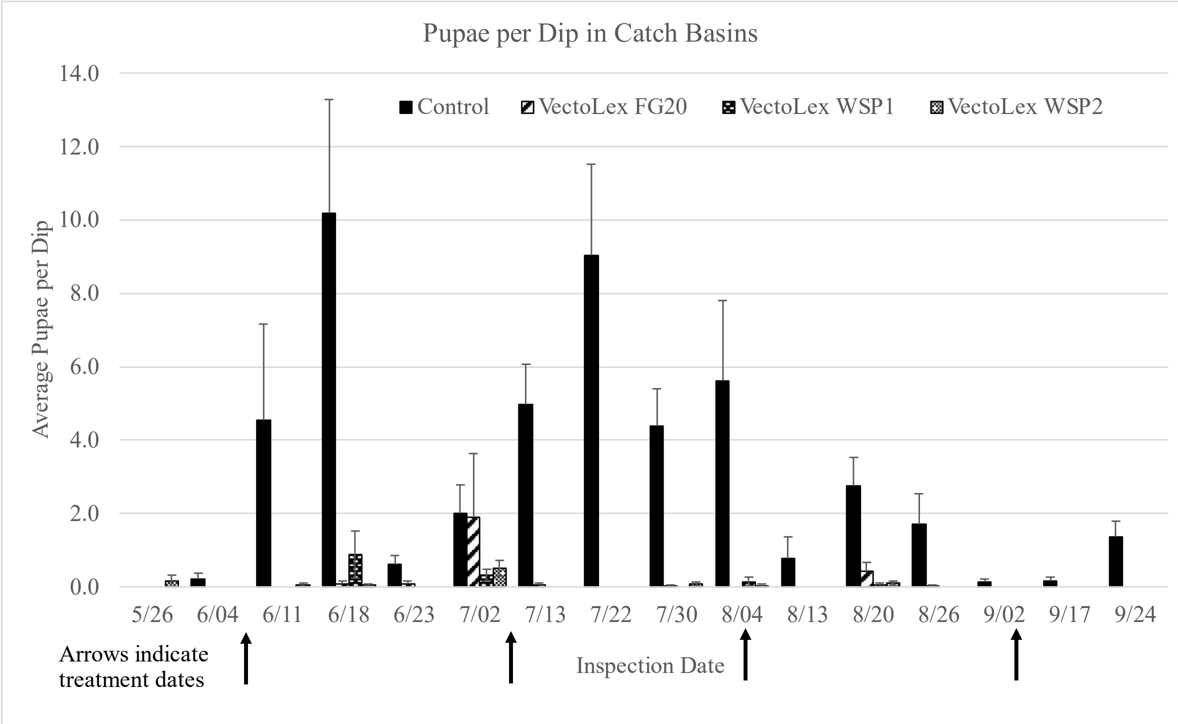


Figure 6.2 Mean number of pupae from untreated (control) and catch basins treated with VectoLex® FG (20 g per catch basin), one or two VectoLex® WSP (10 g per WSP) on each sample date. Error bars equal one Standard Error. Arrows indicate VectoLex® FG and WSP treatment dates.

We also evaluated efficacy using the pass/fail strategy outlined by Harbison et al. (2019). The pass/fail evaluation for direct kill larvicides designates a fail as the presence of one or more late instar larvae (instar 3 or 4) or pupae in a catch basin sample (Harbison et al. 2019). Harbison et al. (2019) recommend retreatment if at least 25% of the catch basins are scored as a fail. Based upon this evaluation method, VectoLex® FG and VectoLex® WSP very effectively controlled vector mosquitoes developing in catch basins. During 14 weeks of sampling (after June 7 treatment), over 25% of catch basins scored fail during three (VectoLex® FG) or four (both VectoLex® WSP treatments) weeks (Table 6.4, Figure 6.3). In contrast, over 25% of untreated catch basins scored fail during 13 of 14 weeks of sampling (Table 6.4, Figure 6.3).

Table 6.4 Percent of catch basins scored as fail from untreated (control) and catch basins treated VectoLex® FG (20 g per catch basin), one or two VectoLex® WSP (10 g per WSP) on each sample date (after June 7 treatment)

	% CBs fail/week		Number of weeks fail	
Material	Mean	(SE*)	<25% CBs Fail	≥25% CBs Fail
VectoLex® FG	17.2%	(5.6%)	11	3
VectoLex® WSP (1)	14.8%	(4.1%)	10	4
VectoLex® WSP (2)	13.6%	(4.7%)	10	4
Untreated Control	70.6%	(6.5%)	1	13

*SE= standard error

Next is the question of how long VectoLex® FG at 20 g and one or two VectoLex® WSP (10 g per WSP) per catch basin effectively control mosquitoes in catch basins. We first explored the possibility that rain could be affecting control. Precipitation was quite low until the fourth week of August which made detecting a relationship difficult. No pattern in the proportion of catch basins scoring fail and rain events equal to or greater than one inch over 24 hours is apparent (Figure 6.3).

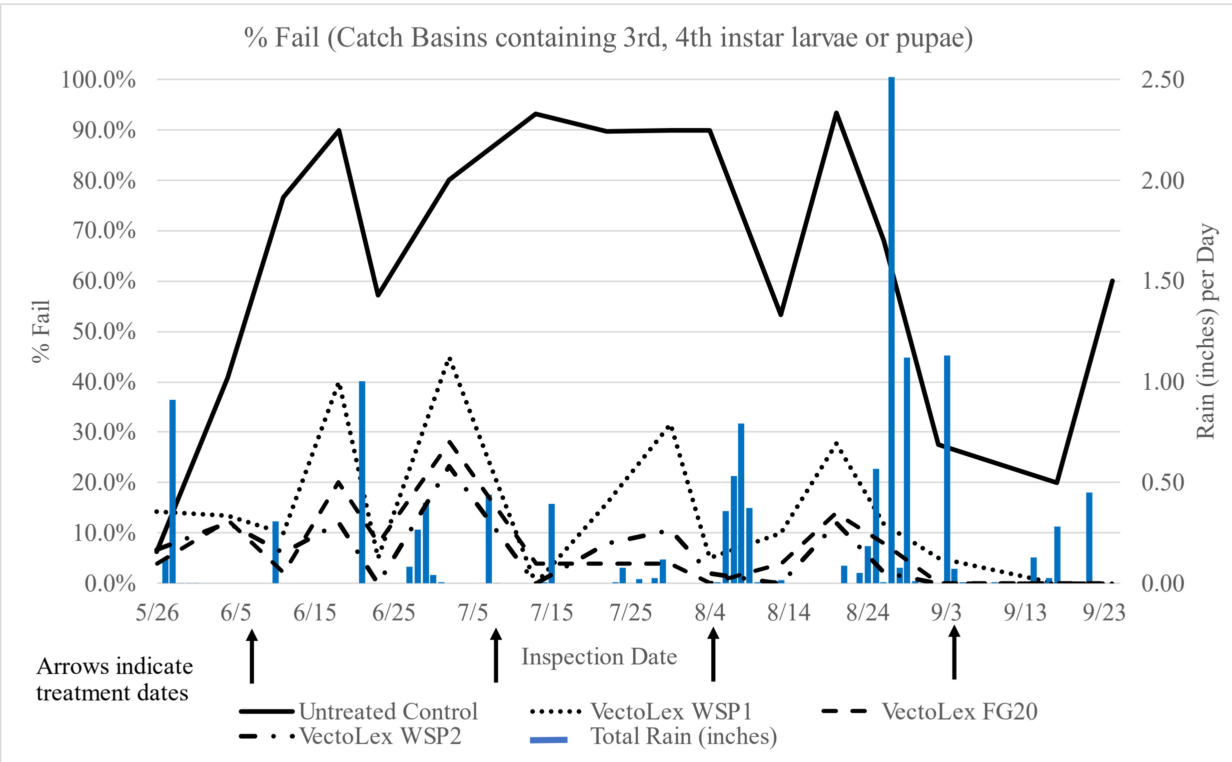


Figure 6.3 Percent of catch basins scored as fail (catch basins containing 3rd or 4th instar larvae or pupae) from untreated (control) and catch basins treated VectoLex® FG (20 g per catch basin), one or two VectoLex® WSP (10 g per WSP) on each sample date including 24-hour total rainfall events.

We used linear least squares regression to evaluate possible impacts of significant flushing rain events (equal to or greater than one inch over 24 hours). Four such rainfall events occurred during the 14-week sampling period (June 21, August 27, August 29, and September 3) after the first VectoLex® treatment on June 7. The percentage of catch basins scored as fail on each sampling date (dependent variable) was compared to the number of days after the most recent significant rain event that the samples was collected (independent variable). Percent fail values were arcsin-transformed for this analysis.

No significant association was observed in untreated catch basins or in catch basins treated with VectoLex® FG (20 g per catch basin) or one or two VectoLex® WSP (10 g per WSP) (Table 6.5, Figure 6.4). Note that R-squared values for each regression line were very low indicating that time after significant rain (≥1.0inch) explained very little of the variation in the data (Figure 6.4). This may be due to very few significant rain events occurring during most of the 14-week sampling period; three of the four rain events (August 27, August 29, and September 3) occurred during a one-week period (Figure 6.3).

Table 6.5 Least squares regression of percent fail (arcsin-transformed) and days after significant rainfall in untreated (control) and catch basins treated with VectoLex® FG (20 g per catch basin), or one or two VectoLex® WSP (10 g per WSP) separately (after June 7 treatment)

Material	Slope (b)	SD* (of slope)	T**	df***	p-value
VectoLex® FG	0.0013	0.00426	0.313	12	0.370
VectoLex® WSP (1)	0.0025	0.00334	0.763	12	0.287
VectoLex® WSP (2)	0.0021	0.00404	0.509	12	0.340
Control	0.0063	0.00513	1.220	12	0.183

*SD = standard deviation; **T = (slope – 0)/SD; ***df = n-2 (n = 14 weeks)

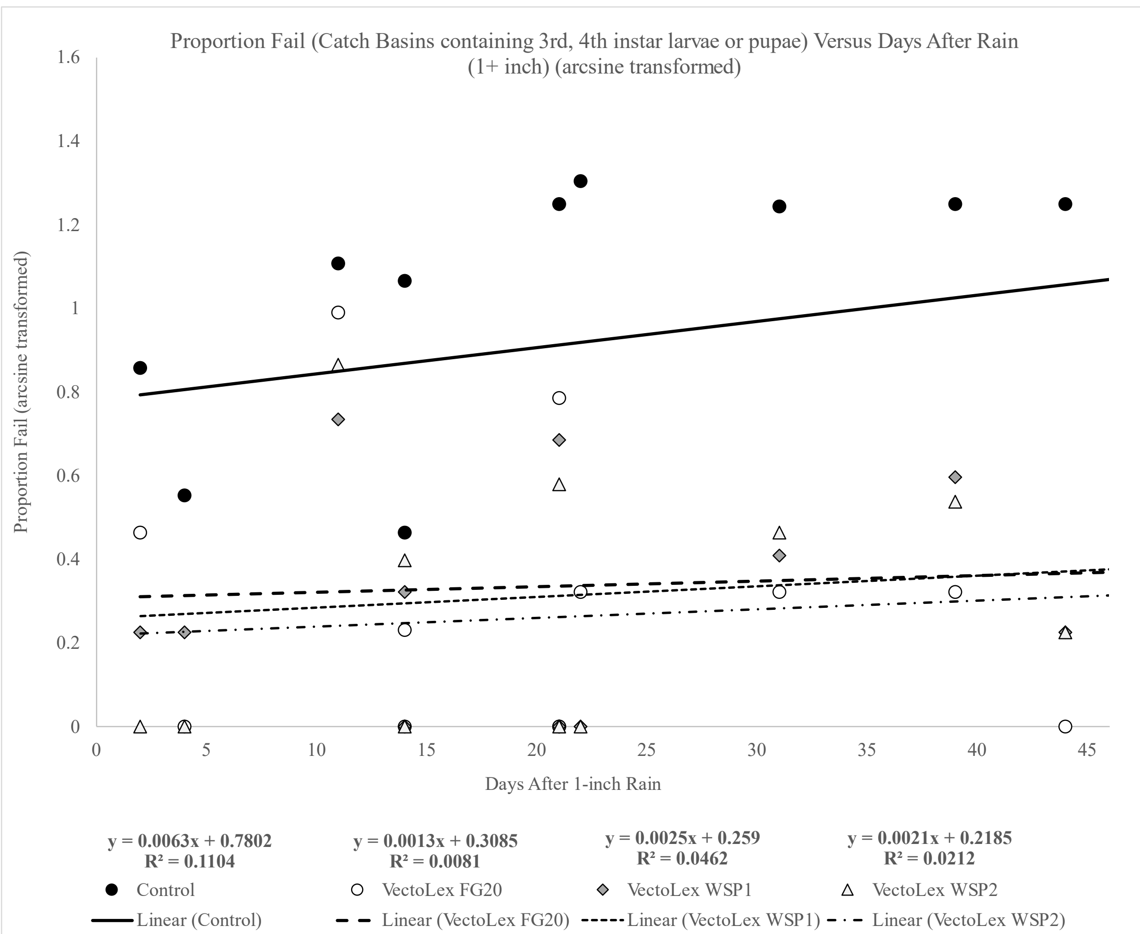


Figure 6.4 Least squares regression lines of percent fail (arcsin-transformed) and days after significant rainfall in untreated (control) and catch basins treated with VectoLex® FG (20 g per catch basin), or one or two VectoLex® WSP (10 g per WSP) separately (after June 7 treatment).

These results suggest that populations of late instar larvae and pupae in untreated catch basins were higher throughout the entire sampling period than in catch basins treated with VectoLex® FG (20 g per catch basin), or one or two VectoLex® WSP (10 g per WSP). Flushing rain events (equal to or greater than one inch over 24 hours) did not significantly affect abundance of late instar larvae and pupae. The number of weeks when more than 25% of the catch basins contained one or more late instar larvae (instar 3 or 4) or pupae in a catch basin sample was lower for all three treatments compared to untreated catch basins. Pupal abundance also was lower in all three treatments compared to untreated catch basins.

We used linear least squares regression to evaluate the apparent duration of control using the 25% fail method achieved by VectoLex® FG and one or two VectoLex® WSP (10 g per WSP). The percent of catch basins scored as fail on each sampling date (dependent variable) was compared to the number of days after the most recent treatment (independent variable). Untreated catch basins were scored (days after treatment) by using the most recent VectoLex® treatment date. Percent fail values were arcsin-transformed for this analysis.

No significant association was observed in untreated catch basins or in catch basins treated with VectoLex® FG (20 g per catch basin) or one or two VectoLex® WSP (10 g per WSP) (Table 6.6, Figure 6.5). Note that R-squared values for each regression line were very low indicating that time after treatment explained very little of the variation in the data (Figure 6.5).

Effective control (fewer than 25% of catch basins scoring fail) in catch basins treated with VectoLex® FG (20 g per catch basin) or one or two VectoLex® WSP (10 g per WSP) apparently lasted at least 28 days, the entire time period between treatments, because no association between % fail and time after treatment was observed. This is similar to results observed in 2020 (25% of VectoLex® FG-treated catch basins will score fail 24.3 days after treatment (95% confidence limits: 19–28 days after treatment) (see 2020 Operational Review and Plans for 2021 for details). Based upon non-overlap of 95% CL (confidence levels), the number of pupae per dip in all three treatments were significantly lower than the number of pupae per dip in untreated catch basins (Table 6.7). Pupal abundance in the three treatments did not differ significantly (Table 6.7). Percent control estimated by comparing mean pupae per dip for each treatment to the untreated catch basins ranged from 94.7% to 98.3% (Table 6.7). All three treatments effectively controlled mosquitos in catch basins for four weeks.

Table 6.6 Least squares regression of percent fail (arcsin-transformed) and days after treatment in untreated (control) and catch basins treated VectoLex® FG (20 g per catch basin), one or two VectoLex® WSP (10 g per WSP) separately (after June 7 treatment)

Material	Slope (b)	SD* (of slope)	T**	df***	p-value
VectoLex® FG	-0.0046	0.01109	-0.416	12	0.3559
VectoLex® WSP (1)	0.0044	0.00885	0.502	12	0.3412
VectoLex® WSP (2)	0.0042	0.01062	0.393	12	0.3595
Control	-0.0052	0.01001	-0.519	12	0.3382

*SD= standard deviation; **T = (slope – 0)/SD; ***df = n-2 (n = 14 weeks)

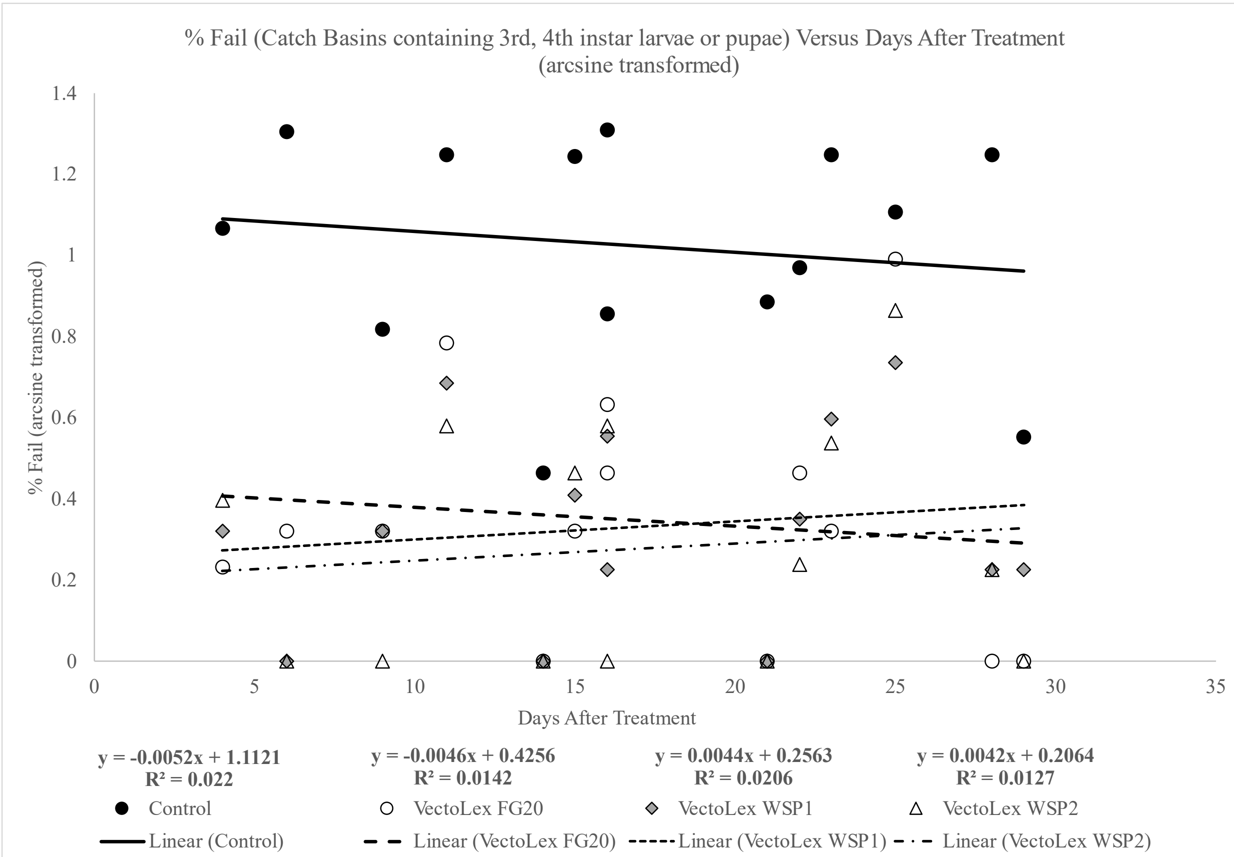


Figure 6.5 Least squares regression lines of percent fail (arcsin-transformed) and days after treatment in untreated (control) and catch basins treated with VectoLex® FG (20 g per catch basin), or one or two VectoLex® WSP (10 g per WSP) separately (after June 7 treatment).

Table 6.7 Pupal abundance (pupae per dip) in untreated (control) and catch basins treated VectoLex® FG (20 g per catch basin), one or two VectoLex® WSP (10 g per WSP) separately (after June 7 treatment).

	Pupae per dip			95% CL***		Percent
Material	Mean	SE*	N**	Lower	Upper	Control§
VectoLex® FG	0.18	0.14	14	0.00	0.53	94.7%
VectoLex® WSP (1)	0.10	0.06	14	0.00	0.26	97.1%
VectoLex® WSP (2)	0.06	0.04	14	0.00	0.15	98.3%
Control	3.44	0.85	14	1.28	5.61	N/A

*SE= standard error; **N = weeks after June 7 treatment; ***Mean ± ($T_{0.975(df\ 13)}$) * (Variance/N)$^{1/2}$); $T_{0.975(df\ 13)}$ = 2.5326
§ 100*((Mean pupae control – Mean pupae treatment)/Mean pupae control)

Adulticide Tests

We did not complete any tests of adulticides in 2021 because of staff limitations due to the COVID-19 pandemic.

Equipment Evaluations

Helicopter Swath Analysis and Calibration Procedures for Larvicides Technical Services and field staff conducted four aerial calibration sessions for dry, granular materials during the 2021 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 in 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.

Drone Swath Analysis and Calibration Procedures for Larvicides Technical Services aided in aerial calibration sessions for the PrecisionVision 22 aerial treatment drone for dry, granular materials in the same manner as we calibrate the helicopters. Staff completed swath characterizations for two control materials applied in 2021 (Altosid® P35 granules and VectoLex FG granules). The PrecisionVision 22 drone we utilized for aerial treatments has a hopper system that can manipulate the swath of the material applied by adjusting the voltage to the hopper. The hopper voltage, combined with the flight speed of the drone, and variously sized flow restrictors affect the swath characterization for the different control materials.

Malvern Laser: ULV Droplet Evaluations Technical Services continued the spray equipment workgroup to evaluate truck-mounted, UTV-mounted, backpack, and handheld ULV generators. We constructed a 20 ft x 40 ft indoor spray booth where we evaluate adulticide application equipment. Using the Malvern laser, staff continued to improve sampling procedures and techniques to evaluate the multiple types of spray equipment. MMCD analyzed the spray characteristics of all our ULV equipment and optimized each spray system with its respective control material. In 2021, Technical Services assisted in measuring droplets for an outside vendor developing nozzles that attach to an all-electric leaf blower. MMCD reviewed the equipment for future evaluation. An all-electric spray unit may become a necessary part of our operations. Other major cities in the US are starting to restrict the use of small combustion engines in areas with air pollution and/or environmental concerns.

Optimizing Efficiencies and Waste Reduction

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

Field offices collected their empty, triple-rinsed plastic containers at their facility and packaged them in large plastic bags for recycling. Each facility delivered their empty jugs to the Rosemount warehouse for pickup by the MDA contractor, Consolidated Container. MMCD staff collected 129 jugs for this recycling program. The low number of containers were properly stored for future disposal. The control materials that use plastic 2.5-gallon containers are Anvil® 2-2 (1 jug), Zenivex® E4 RTU (10 jugs), *Bti* liquid (72 jugs), and Altosid® pellets (46 jugs). A majority of the *Bti* liquid came in bulk totes, and the reduced overall use of adulticides due to the low mosquito numbers significantly reduced the number of jugs generated in 2021.

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

Recycling Insecticide Pallets In 2021, MMCD produced over 320 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. We would like to eliminate a significant portion of these unrecyclable insecticide bags. Staff is attempting to keep these bags out of landfills, and instead directing them to garbage burner facilities where some public benefit of the generated waste can be realized.

The District continues to expand use of refillable totes in the helicopter loading operations. MMCD is working with three manufacturers to ship bulk larvicides in reusable pallet sized totes. In 2021, Clarke shipped all of our Natular® G30 granules (44,800 lb) in 28 totes and reduced our packaging use by 1,120 bags. In 2021, Central Life Sciences shipped Altosid® P35 granules (78,000 lb) in 39 totes and reduced the packaging by 1,950 bags. Valent sent MetaLarv® granules (55,000 lb) in bulk totes and reduced the packaging by 1,375 bags. Valent also sent a portion of VectoBac® 12-AS liquid (1,056 gallons) in bulk totes and reduced the packaging by 422 jugs. Staff was able to spend less time dealing with waste, and the District eliminated 4,867 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 2021, Valent BioSciences agreed to take back all of their products' waste packaging. Due to the quantity of *Bti* and VectoLex FG granules used (470,086 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 17,628 lb was eliminated from the waste stream.

References

Harbison, J. E., R.S. Nasci, and M. Clifton. 2019. Operational quality control for catch basin larviciding at the North Shore MAD. Wing Beats. 30: 5-13. Summer 2019.

2022 Plans – Product and Equipment Testing

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

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

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

We will attempt to collect additional efficacy data on our current operational control materials and provide more quality information to staff in which to base decisions.

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

Chapter 7 Supporting Work

2021 Highlights

- Expanded larvicide treatments from a drone (UAS) in regular operations
- Continued use of drones for aerial photography and site scouting
- Created new form on MMCD website that sends public requests directly into field system, reducing workload for staff handling calls and improving data capture
- Transitioned desktop map software to QGIS
- Continued upgrade of field data system servers and software base
- Developed IPM Plans and Pest Alerts to improve communication, planning and evaluation
- Low mosquito numbers correlated with record low number of calls requesting adult treatment
- Public interactions returned to mix of in-person plus new videos

2022 Plans

- Continue testing drone-based granular treatments and how that process can fit into MMCD operations
- Test and implement new ways to record catch basin treatments electronically
- Finish IPM Plans, use in training and work planning, and use in year-end assessment

2021 Projects

Unmanned Aircraft Systems (Drones)

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

The drone workgroup at MMCD is tasked with training staff to operate UAS, test various uses for these platforms, and guide the future directions of drone usage within the District. Currently, 10 employees are certified as UAS pilots under the FAA's Part 107 regulation which covers commercial uses for drones weighing less than 55 pounds. In addition, two employees have also obtained their Category B license (pesticide application with an aircraft) which allows them to treat sites via UAS in Minnesota.

Figure 7.1 DJI Mavic drone

In 2021, we utilized our three, small quadcopters for scouting and photography purposes (Fig. 7.1). The main use was to photograph sites to update our internal map imagery. This was necessary for areas with outdated imagery and recently constructed areas that altered the landscape by either eliminating or creating new mosquito breeding sites. Drones can be useful to investigate treacherous wetland habitats (e.g., floating cattail mats) and large (100+ acre) wetlands that would require additional staff to search for access points and suitable areas to survey mosquito larvae. Additionally, drones have been utilized to produce internal videos, staff photographs, and inspect hard-to-access, potential mosquito habitats like unmaintained swimming pools and water accumulating on rooftops.

During the 2021 mosquito season, we continued to test the operation, ease-of-use, and effectiveness of granular treatments by drone (Fig. 7.2). We had already met the requirements in 2020, including the following:

- We submitted and received a COA (Certificate of Waiver or Authorization) from the FAA in 2020 which grants us the ability to apply control materials from our treatment drone but needs to be renewed every two years.
- Our UAS was registered with both the FAA and MnDOT.
- Our pilots obtained an aerial applicators license from MDA as well as FAA Part 107.

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 drone was calibrated for both Altosid® P35 and VectoLex® (see Chapter 6). In 2020, we had treated 29 sites (39.5 acres) with 592.45 lb of VectoLex®, replacing ~ 13,000 Altosid® briquets. This decreased in 2021 to 18 sites (22.34 acres) with 335 lb of VectoLex®, replacing ~7,350 briquets, due to many cattail sites drying up. In 2020, we had treated 34 sites (48.19 acres) with 127.72 lb of Altosid® P35. In 2021, this increased to 114 sites (160.55 acres, 479.44 lb) – more than three times the number of sites and acres treated in the previous year. Staff who used the treatment drone learned to deal with the quirks of new technology and were enthusiastic about its ability to provide a quality treatment without the physical challenge of ground-based applications, especially in sites with high vegetation.

Figure 7.2 Preparing for treatment using UAS. Seasonal Field Technicians appreciated the help and started to learn to work with the drone.

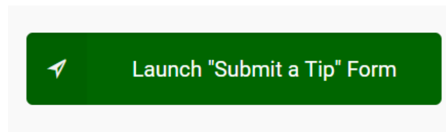
We anticipate drones will facilitate cost savings for the District by increasing efficiency of larval inspections and treatments (from up-to-date maps, identifying access points, and decreasing staff time in cumbersome sites) and replacing costly briquet treatments with cheaper granular applications at hard-to-treat cattail sites. Also, we believe that using drones to treat difficult and dangerous sites has significant safety advantages.

Plans for 2022 We will continue using photo drones to update aerial imagery and to scout sites as needed. We would like to find better ways to determine water extent, which can be difficult to see in dense vegetation, but would facilitate partial treatments of large wetlands. Photo drones continue to be useful for investigating water holding areas and taking informational videos and 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 2022 is continuing site treatments by drone and finding ways to expand the number of treatment pilots in a way that fits with our seasonal needs and hiring practices. We plan to continue testing under which scenarios UAS treatments are most advantageous; this includes continuing to replace briquet sites and seeing how helpful drone treatments are for pre-hatch control. Tests in 2020 suggested that drone use has the most benefit for increased staff efficiency when used on 1-3 acre sites. Smaller sites can often be done easily by ground, and larger sites can be done by helicopter. We tested the efficiency of drone treatments by comparing the time it takes to treat by drone versus traditional methods and estimate that drone treatments have the potential to treat ~90% more acreage than sites treated by hand in the same amount of time. We may also gather data on the uniformity of these treatments in 2022.

Data Systems & Mapping

In 2021, we continued with some significant changes in our web-based enterprise data system "Webster" developed by Houston Engineering Inc.



- Members of the public can now fill out a form to report annoyance or other concerns directly through our www.mmcd.org website. The messages are geocoded, sorted by field area, and can be accessed directly by the Field Operations Supervisor for response. This promoted accuracy in information capture and simplified the workflow for staff answering calls, We expect to see more impact from it in years with higher annoyance levels.
- New cloud-based servers set up in late 2020 for the Webster database and interface needed adjustments when higher number of users returned for the season. We made changes in both software and server set-up to meet the load. The helicopter tracking service we use also changed servers and we updated our connection software.
- We continued to move parts of the Webster interface to an updated software base that takes care of some issues and will allow for modular development.
- The Catch Basin editor interface, which allows staff to update location info from desk or field and see city data, was redone in the new software resulting in a more stable user experience (Fig. 7.3). A new map-based Catch Basin treatment interface was developed and will be rolled out in spring 2022. We plan to move Mobile Maps, part of the Webster field interface that lets users look up information on sites and get driving directions, to the new software base in 2022, and add more tools for displaying work status and plans.
- We added tools that give users more ability to update data themselves, including a new

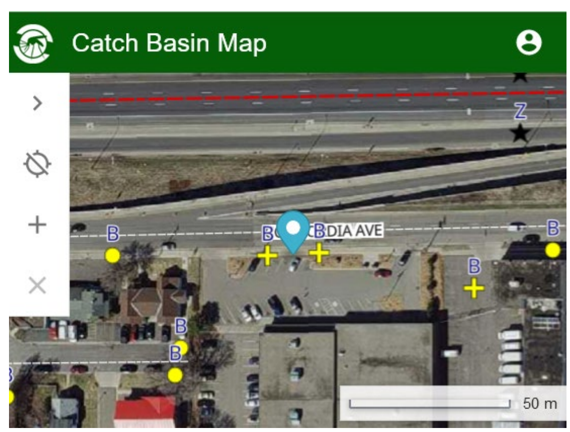


Figure 7.3 Catch Basin editor map interface in Webster

form to manage vehicle and equipment lists, tools for uploading reference documents, and tools for supervisors to manage technicians' material use data.

- We continued to expand capabilities for drone treatment recording.
- We expanded the ability to record water temperatures with larval inspections to support studies on spring mosquito biology.

We made some changes in the interface and in the database to make historical larval and adult collection data more easily available. We plan more work on that in 2022, including QA and standardization of older data and finding better query and visualization tools. This data is important for both our own evaluations and for sharing data with other researchers and practitioners regionally and beyond.

We continued changing our desktop Geographic Information System (GIS) from MapInfo to the widely-used open source program QGIS. Many staff transitioned completely to QGIS at the beginning of 2021, and the rest are completing the transition. We developed training documentation and videos and have used the extensive support available on the web. As of January 1, 2022, we translated our GIS files to the more robust GeoPackage format that can be used in QGIS, marking the end of MapInfo use for general work. A number of specialty mapping projects still need to be redone in the new system. We are starting to explore the opportunities QGIS provides for desktop interaction with our cloud database.

Work-from-home options in response to COVID-19 continued for many workers, especially in the off-season. IT staff continued support for this option and for software and network tools to allow for more remote access. Access considerations have affected many of our software and design choices, favoring options that allow use from any platform.

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 our 82,205 sites in real time and access history back to 2006. Inspection and treatment information is updated automatically from our "Webster" data system. Web stats showed 3,837 access clicks, suggesting somewhat higher use than telephone calls, and a small decline from the 4,027 clicks in 2020. The bulk of public map use was in April-June, about a month earlier than last year.

GIS Community MMCD staff participate in the MetroGIS collaborative, and we benefit from work by many other units of government. In 2021-2022, we are using census data to re-evaluate population density to determine our appropriate service areas. We depend on aerial photos collected by Metropolitan Council and metro-area counties for our wetland mapping, and MMCD staff participate in the Governor's Advisory Council Image Service Sustainability Committee. MMCD also uses basemap and geocoder services from the Metropolitan Council. We share our wetland data through MnGeo's Geospatial Commons.

Spring Degree Day Study

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

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

Figure 7.4 shows the cumulative sum of DD_{40F} from Jan 1 by week of the year (DD value at end of week), for each year from 1993-2021. 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 2021, the DD_{40F} total went over 200 in week 14 (ending April 10), relatively early compared to most dates in the last 20 years. However, temperatures cooled again which slowed larval development. Aerial treatments for spring *Aedes* (gray boxes) began two weeks later and were completed by May 8. Aerial treatments are not started until a sufficient number of sites are over threshold, seasonal technicians are hired, and helicopters have been calibrated.

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 (see Publications below). Earlier publications and reports on Wright County Long-term Study and other studies on *Bti* and methoprene done under the direction of the Scientific Peer Review Panel (SPRP) continue to be available on the MMCD website at https://mmcd.org/non-target-impact-studies/ and web use stats show it was downloaded 190 times in 2021 (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 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 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 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.

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

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	Last date in week (2021)
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	
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	
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	
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	
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	
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	
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	
8	0	0	0	0	0	17	0	20	0	8	3	0	6	0	0	0	1	0	0	3	0	0	0	6	41	0	0	0	0	
9	0	4	0	0	0	17	0	39	0	8	3	2	6	0	0	0	1	0	0	3	0	0	0	6	41	0	0	0	0	
10	0	4	5	0	0	17	0	104	0	8	3	2	13	4	0	0	1	4	0	18	0	0	47	20	60	0	0	4	31	
11	0	9	61	12	0	17	2	104	0	8	19	3	13	4	20	2	30	49	6	135	0	3	76	104	60	0	0	16	39	
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	**Mar 27**
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	**Apr 3**
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**	**Apr 10**
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	**Apr 17**
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	**Apr 24**
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	**May 1**
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	**May 8**
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	**May 15**
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	**May 22**
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	**May 29**
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	**Jun 5**
23	993	1152	970	753	811	1345	1290	1305	1060	913	1093	1204	1292	1417	1457	873	1202	1512	1121	1681	868	944	1356	1408	1345	1057	974	845	1472	**Jun 12**
24	1153	1392	1192	967	1017	1558	1424	1462	1276	1117	1273	1388	1500	1633	1732	1059	1432	1721	1316	1881	1067	1111	1565	1635	1591	1260	1156	1262	1722	**Jun 19**

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

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

Monarch Butterfly - In December 2020, the U.S. Fish and Wildlife Service announced that the monarch was a candidate for listing under the Endangered Species Act, and status would be reviewed annually. MMCD has been 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 2020, we provided information on MMCD operations in relation to monarch protection that they used to revise their website F.A.Q. In July 2021, we provided a webinar for their group on the topic of “Aligning mosquito control with pollinator protection”. That same month an Education Coordinator for MJV presented about monarch migration for MMCD staff at our annual pesticide applicator recertification workshop.

MMCD staff 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 U.S. Fish & Wildlife Service (FWS) regarding mosquito surveillance on and near FWS lands within the District. If rainfall, river levels, or other nearby surveillance indicates a need for sampling, work in the Minnesota Valley National Wildlife Refuge (MVNWR) is conducted following the stipulations of a Special Use Permit updated annually by the refuge manager. “Emergency Response Procedures” and “Pesticide Use Proposals” for the larvicide *Bacillus sphaericus* (VectoLex®) and the adulticide sumithrin (Anvil®) prepared in 2009 by FWS staff allow treatment of disease vectors if “a mosquito-borne disease human health emergency exists in vicinity of the Refuge” (agreed on by MDH, FWS, and MMCD) and such treatment “is found to be appropriate.” An annual analysis of adult mosquito counts around the MVNWR is done by MMCD staff based on the CO_2 trap locations in Figure 7.5.

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. In 2021, drought conditions favored *Cx. pipiens* and *Cx. restuans* and collections of the two species were higher than normal in six of the eight locations monitored near MVNWR.

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 larval surveillance on the MVNWR is *Culex tarsalis,* a competent vector of WNV to humans. *Culex tarsalis* adult counts across most of MMCD were low in 2021 with a season average of 1.54 per CO_2-baited light trap. The season's mean collection in traps near MVNWR was higher at 5.76, strongly influenced by high counts from one location (H291), plus above-normal contributions from the FS1 and DSR7 locations. This marks a contrast with 2020 when *Cx. tarsalis* numbers were at a historic low.

Mosquitoes collected from traps near MVNWR were tested for WNV from the beginning of June through the end of September 2021. In August, WNV positive pools were found in two *Cx. tarsalis* samples and one *Cx. restuans/pipiens* sample from the FS1 location, and one *Cx. tarsalis* sample from H291. This is another contrast with 2020, when no samples from the area tested positive for WNV.

Mean collections of *Aedes vexans* were lower than during most years due to dry conditions. The peak rate of capture occurred on August 24 at 426 per trap following significant rainfall. Only two of the eight traps monitored near MVNWR had season average collections of *Ae. vexans* in excess of 100 rather than the more typical four to six traps. For traps near MVNWR, collections of *Ae. vexans* were greatest within one mile of the refuge.

Low water levels persisted in the Minnesota River valley through much of 2021 and, as a result, MMCD did not request permission to conduct larval mosquito surveillance within MVNWR.

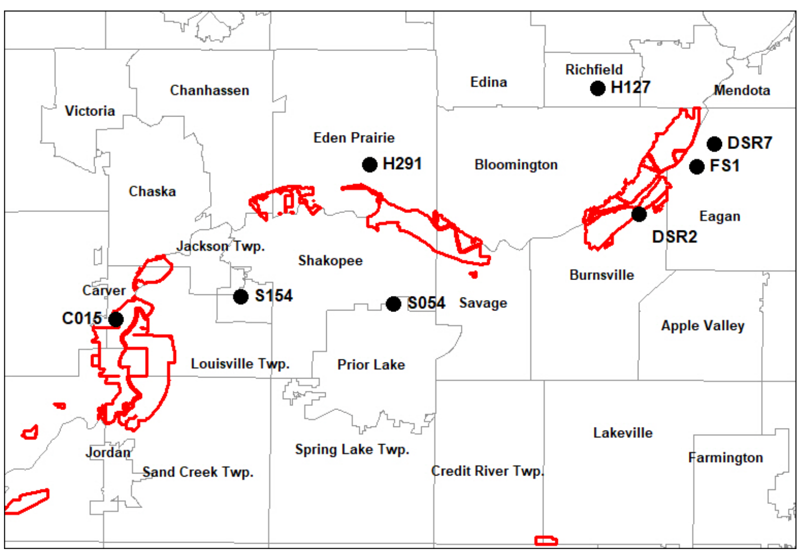


Figure 7.5 CO_2 trap locations (circles) near the Minnesota Valley National Wildlife Refuge. Solid, dark lines delineate refuge boundaries.

Integrated Pest Management Plans

In 2021 MMCD evaluated its Team structure to look for ways we could more effectively use staff time and skills and provide service. We reorganized some teams, and re-focused on how we talk about what we do in relationship to Integrated Pest Management (IPM). We decided to develop and document more specific IPM plans as a way to:

- Make sure we have a common understanding of what we do and why
- Have an easy way to find the basis for our surveillance and control practices
- Have a quick intro for new employees
- Help us discover what's going well and what we can improve

The Technical Services Team developed two IPM plan templates as a guide to develop consistent plans that cover IPM basics for different species. The template topics were based on descriptions of IPM in the MN Category L Handbook – Chapter 6 "Intro to Integrated Mosquito Management," the National Pesticide Applicator Certification core manual, AMCA "Best Practices for Mosquito Control 2017: A Focused Update," and MMCD's history of problem-solving training. The full plan "Framework" is the basis for documenting the information needed to understand a problem and develop and evaluate control strategies. The "Pest Alert" format (Fig. 7.6) uses the same outline as the Framework, but provides a brief overview aimed at training new staff and serving as a quick reference.

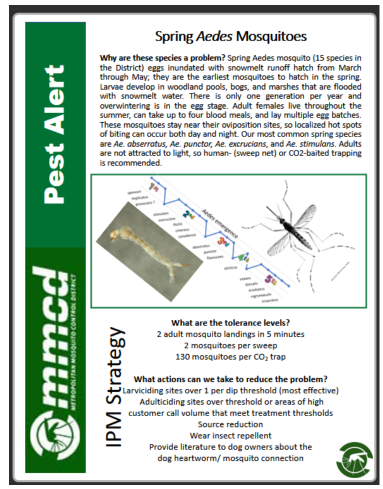


Figure 7.6 IPM Pest Alert Example

The Framework is based on the following questions:

1. Why is this species (or group) a problem? (Example: human biting, vector of EEE) The IPM plan may change if a species becomes a vector.
2. What are the tolerance levels? (Example: 2 adult mosquito landings in 5 min) Includes links to research. Note this is the tolerance level of the 'problem', other action thresholds may be set to keep the final population at or below tolerance. For disease species 'tolerance' is harder to define, may depend on disease circulation.
3. Where and when are those levels exceeded? (Example: surveillance maps by date, seasonality)
4. What action can we take to reduce the problem? (and not cause more problems)
   - Public Education (Examples: Tick Meter, promoting mosquito repellent use)
   - Prevention (Examples: reduce container habitats, design stormwater structures, mow trails to reduce tick access) Benefits, potential impacts
   - Treatment (Examples: set larval action thresholds needed to prevent adults, check which sites exceed thresholds, apply controls) Avoid other impacts: use lowest effective dose, target applications at pest, choose timing to reduce exposure, choose low-impact materials, monitor for resistance
5. How do we know we've reduced the problem, and show that to the public? (Examples: Adult mosquito surveillance showing if tolerance level was exceeded, or comparing treated vs untreated areas; disease incidence)

The Framework is designed to be broad and flexible to encourage exploring new solutions to pest problems that may be different from conventional treatments.

By the end of 2021 we had 6 groups of Tech & Field staff working on IPM plans for 10 species groups. In early 2022, we will finish drafts of these plans and develop "Pest Alerts" for each. We will review the plans before the field season starts, and set up check points and evaluation criteria to monitor progress through the summer. We will revisit each plan and evaluate if changes are needed in the fall.

Public Communication

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

Calls Requesting Service Due to dry weather and a low population of annoyance mosquitoes throughout July and August of 2021, calls requesting treatment were very low compared to previous years. In 2021, the number of these calls peaked the week of June 7th, which coincides with the peak of mosquitoes collected in sweeps (Figure 7.7). Calls declined quickly at the end of June and remained low throughout most of the rest of the season, thanks in part to less rain and lower mosquito counts.

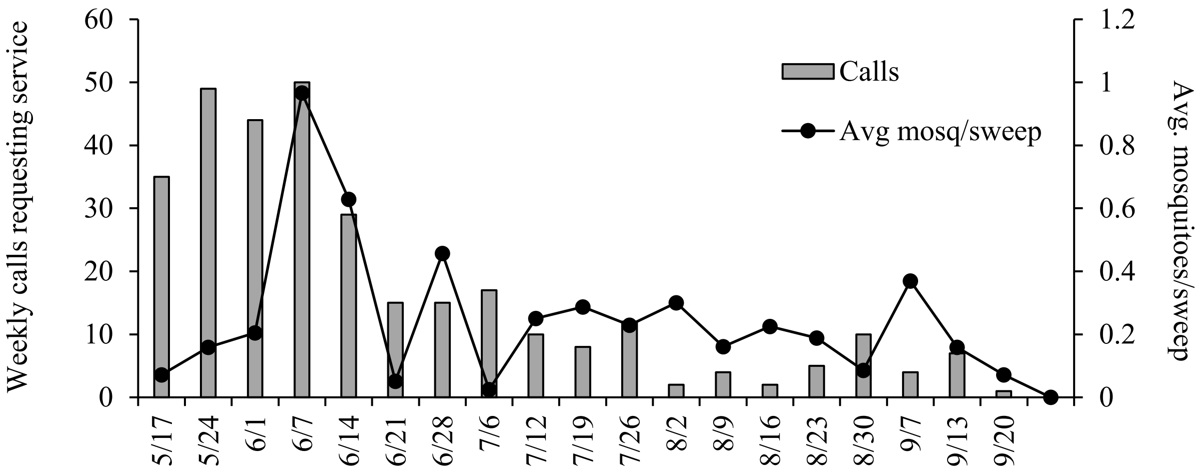


Figure 7.7 Calls requesting service and sweep net counts, by week, 2021.

Requests specifically asking for adult mosquito treatment or to check breeding sites in 2021 were down significantly compared to recent years (Table 7.1). From 2011-2020, the average number of calls to request adult mosquito treatments was 1,566 per year and in 2021 MMCD received only 176 calls for that reason. The drop can largely be explained by the lack of annoyance mosquitoes during peak months. Requests for treatment at public events ticked back up in 2021 as many in-person events returned after taking 2020 off due to concerns surrounding the COVID-19 pandemic. Tire pick up calls and requests for limited or no treatment remained about the same as in previous years.

Table 7.1 Yearly citizen call totals (including e-mails) by service request type, 2011-2021

	Number of calls by year										
Service request type	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Check a larval site	626	539	609	1,068	447	886	1,151	601	802	438	234
Request adult treatment	1,291	1,413	1,825	2,454	1,633	2,499	1,157	1,212	1,144	1,030	176
Public event, request treatment	67	61	70	93	91	105	101	91	71	12	43
Request tire removal	315	417	351	429	366	377	363	325	411	411	377
Request or confirm limited or no treatment	56	54	[a]136	[b]146	139	158	126	75	69	76	73

[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 2021, mmcd.org had 32,383 unique visitors which was up from 29,923 in 2020.

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. There were 353 calls that came in through the new contact form.

Community and School Presentations Due to the COVID-19 pandemic, MMCD did not participate in as many in-person school presentations or community presentations in 2021 as in years prior to the start of the pandemic. However, as an organization we did participate in four in-person classroom presentations and seven virtual presentations. Many of these presentations were for multiple classes at a single school and took up most of the day. We also continued to offer our pre-recorded 18-minute classroom presentation to teachers and parents, which was viewed another 120 times in 2021.

Given the lack of public meetings, we continued to release video content on our website and social media channels to educate the public. In 2021, we released several videos including "5 Tips for Reducing Mosquitoes in Your Yard," and "Cattail Season" to educate about cattail mosquitoes (*Coquillettidia perturbans*).

Screenshots from 2021 MMCD videos "Cattail Season" (left) and "5 Tips for Reducing Mosquitoes" (right).

Public Events After very few public events in 2020, MMCD returned to participate in several in-person community events in 2021. The biggest event of the year was the Minnesota State Fair where District staff had conversations with over 3,900 people during the 12-day event. MMCD also attended county fairs in Anoka, Dakota, Carver, Scott, and Washington counties and several city events. We also participated in nine parades throughout the District where we featured our mosquito mascot who was newly named "Vectoria" in 2021 after an online survey asking for name suggestions.

Social Media As part of an ongoing effort to notify residents when and where treatment is to take place and to offer another point of contact for the District, MMCD has maintained a presence on Facebook, Twitter, and Instagram. In 2021, the District also added a TikTok account, which was maintained by the East facility to interact with a new audience. MMCD currently has 863 Twitter followers, up from 759 followers at the end of 2020; 1,733 page followers on Facebook, up from 1,540 in 2020; and 332 followers on Instagram, up from 218 at the end of 2020.

MMCD also uses Granicus to give advance notification to District residents of adult mosquito treatments, and to distribute press releases and make announcements about job openings. 2021 ended with 8,224 individual subscribers who opted in to receiving some sort of communications from MMCD, which is up from 7,242 at the end of 2020.

Sustainability Initiative

MMCD's Sustainability Initiative began in 2013 and examines the economic, environmental, and social impacts of adopting sustainable practices throughout District operation. We keep sustainability in mind with all operations, and our Sustainability Team leads many efforts and brings suggestions to other teams. Some activities have been scaled back since COVID-19, but most processes developed in previous years were carried forward.

Reducing Energy Usage For electricity, we are continuing the transition to LED lights and are seeing significant energy and cost savings. We are looking into our vehicle fleet options for fuel savings. Virtual meetings and work-from-home options have increased overall savings.

Reducing Waste We continue our pesticide container recycling and reuse program in cooperation with the manufacturers. We've also continued to use bulk containers for the delivery of several control materials (see Chapter 6 for more details). Composting is widely used for items such as food scraps and paper towels, and we continue to make general recycling as accessible as possible to all staff at each location.

Renewable Energy Six of our seven offices are signed up to receive electricity from solar gardens through solar programs that will also reduce our electricity cost.

Social Responsibility and Wellness This area includes how we give back to and take care of our community and promote the health of our staff. We continue to participate in donation drives for food and goods and have also started vegetable gardens and/or native plantings at most facilities.

Professional Association Support

American Mosquito Control Association MMCD staff members continued to provide support for the national association. Mark Smith serves as a member of the AMCA Science and Technology Committee and represents the North Central Mosquito Control Association at the AMCA regional associations' presidents meeting. Kirk Johnson is on the Federal Lands Subcommittee of the Legislative and Regulatory Committee.

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

North American Black Fly Association John Walz serves as President and Carey LaMere maintains the association's website, https://nabfa.org/. Due to COVID-19, the 2021 meeting was canceled. NABFA had hoped to meet in February 2022 but canceled again.

North Central Mosquito Control Association Mark Smith and Scott Larson served on the Board of Directors of this regional association for Minnesota, North Dakota, South Dakota, Wisconsin, Iowa, and the central provinces of Canada. The 2021 annual meeting was held as a virtual meeting and was free to attend. The 2022 annual meeting, April 6, is planned for virtual as well. The meeting qualifies attendees for pesticide applicator re-certification for Minnesota and North Dakota. Visit their website to learn more at http://north-central-mosquito.org/.

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 2021 and talks that are planned in 2022.

Publications

Crane, D.M., C.A. LaMere, R.D. Moon, and S.A. Manweiler. 2021. Efficacy and nontarget effects of a spinosad-based larvicide in Minnesota vernal pools and cattail marshes. J. Am. Mosq. Control Assoc. 37(3): 125-131.

Larson, S.R., A.E. Sabo, E. Kruger, P. Jones, and S.M. Paskewitz. 2021. *Ixodes scapularis* density in U.S. temperate forests shaped by deer, earthworms, and disparate factors at two scales. Ecosphere (forthcoming).

Mittelstet, B., S. Colianni, L. King-Schultz, A. Bjorklund, C. LaMere, V.E. Nambudiri, and K. Subrahmanian. 2021. Posterior hairline eruption secondary to *Simulium* bites. The Journal of Pediatrics, 237, pp. 309-310.

2021 Presentations & Posters

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

Carlson, A. 2021. Aligning mosquito control with pollinator protection. Monarch Joint Venture Webinar Series (virtual).

Davis, T. 2021. Safe operations – Pesticides. North Central Mosquito Control Association Annual Meeting (virtual) and MDA Category L Pesticide Applicator Recertification Workshop - MMCD (virtual).

Jarnefeld, J. 2021. Tickborne disease update and important tick-related reminders. MDA Category L Pesticide Applicator Recertification Workshop - MMCD (Virtual)

Johnson, K. 2021. Catch basin larvicide efficacy tests. MDA Category L Pesticide Applicator Recertification Workshop - MMCD (virtual).

Larson, S. 2021. Drone use in mosquito control. North Central Mosquito Control Association Annual Meeting (virtual).

Moua, A. 2021. Emerging techniques for mosquito control from around the world. North Central Mosquito Control Association Annual Meeting (virtual) and MDA Category L Pesticide Applicator Recertification Workshop - MMCD (virtual).

Read, N. 2021. Integrated pest management (IPM) as problem solving. MDA Category L Pesticide Applicator Recertification Workshop - MMCD (virtual).

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

Smith, M. 2021. Applying low methoprene rates by aircraft. Valent BioSciences Educational Summit (virtual).

Smith, M. 2021. Overview of integrated pest management. North Central Mosquito Control Association Annual Meeting (virtual).

Smith, M. 2021. Pesticide waste – What to do with it. North Central Mosquito Control Association Annual Meeting (virtual).

Smith, M. 2021. Association management update. North Central Mosquito Control Association Annual Meeting (virtual).

Smith, M. 2021. Impacts of Covid-19 on mosquito control operations – Roundtable discussion. North Central Mosquito Control Association Annual Meeting (virtual).

2022 Presentations & Posters

Johnson, K. 2022 Impacts of climate change and weather extremes on mosquito-borne disease. Minnesota Structural Pest Management Conference, March 7, 2022 (virtual).

Manweiler, S. 2022. *Simulium tuberosum*, the newest biting gnat problem in the Greater Minneapolis – Saint Paul area. Annual Meeting of the Michigan Mosquito Control Association, February 2, 2022 (virtual).

Manweiler, S. 2022. Mosquito control and the Endangered Species Act. Minnesota Structural Pest Management, March 7, 2022 (virtual).

Parent, M. 2022. Partial site treatments by helicopter. American Mosquito Control Association Annual Meeting, February 28 (Jacksonville, Florida).

Smith, M. 2022. Review of your IPM plan can refocus your organization. American Mosquito Control Association Annual Meeting, February 28 (Jacksonville, Florida).

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 1965-2021 (identifications in progress)
APPENDIX C	Description of Control Materials
APPENDIX D	2021 Control Materials: Percent Active Ingredient (AI), AI Identity, Per Acre Dosage, AI Applied Per Acre, and Field Life
APPENDIX E	Acres Treated with Control Materials Used by MMCD for Mosquito and Black Fly Control for 2013-2021
APPENDIX F	Graphs of Larvicide, Adulticide, and ULV Fog Treatment Acres, 1984-2021
APPENDIX G	Control Material Labels (separate file for TAB meeting)

APPENDIX A Mosquito and Black Fly Biology and Species List

Mosquito Biology

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

Disease Vectors

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

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

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

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

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

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

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

Floodwater Mosquitoes

Spring *Aedes* Spring *Aedes* mosquito (15 species in the District) eggs inundated with snowmelt runoff hatch from March through May; they are the earliest mosquitoes to hatch in the spring. Larvae develop in woodland pools, bogs, and marshes that are flooded with snowmelt water. There is only one generation per year and overwintering is in the egg stage. Adult females live throughout the summer, can take up to four blood meals, and lay multiple egg batches. These mosquitoes stay near their oviposition sites, so localized hot spots of biting can occur both day and night. Our most common spring species are *Ae. abserratus, Ae. punctor*, *Ae. excrucians,* and *Ae. stimulans*. Adults are not attracted to light, so human- (sweep net) or CO_2-baited trapping is recommended.

Summer Floodwater *Aedes* Eggs of summer floodwater *Aedes* (5 species) can hatch beginning in late April and early May. These mosquitoes lay their eggs at the margins of grassy depressions, marshes, and along river flood plains; floodwater from heavy rains (greater than one inch) stimulate the eggs to hatch. Overwintering is in the egg stage. Adult females live about three weeks and can lay multiple batches of eggs, which can hatch during the current summer after flooding, resulting in multiple generations per year. Most species can fly great distances and are highly attracted to light. Peak biting activity is as at dusk. The floodwater mosquito, *Ae. vexans*, is our most numerous pest. Other common summer species are *Ae. canadensis*, *Ae. cinereus*, *Ae. sticticus,* and *Ae. trivittatus*. New Jersey light traps, CO_2-baited traps, and human-baited sweep net collections are effective methods for adult surveillance of these species.

***Psorophora* Species** Larvae of this genus develop in floodwater areas. The adults will feed on humans. Numerous viruses have been isolated from species in this genus, however, there is no confirmation that these species transmit pathogens that cause human disease in the District. Four species occur here: *Psorophora ciliata*, *Ps. columbiae*, *Ps. ferox*, and *Ps. horrida*. Although considered rare or uncommon, they have been detected more frequently since the mid-2000s. The adult *Ps. ciliata* is the largest mosquito found in the District, and its larvae are predacious and even cannibalistic, feeding on other mosquito larvae.

Cattail Mosquito

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

Permanent Water Species

Other mosquito species not previously mentioned develop in permanent and semi-permanent sites. These mosquitoes comprise the remaining *Anopheles*, *Culex*, and *Culiseta* species as well as *Uranotaenia sapphirina.* These mosquitoes are multi-brooded and lay their eggs in rafts on the surface of the water. Adults prefer to feed on birds or livestock but will bite humans (except for *Ur. sapphirina* which feeds exclusively on annelids and *Cx. territans* which feeds on amphibians and snakes). They overwinter in places like caves, hollow logs, stumps, or buildings.

Invasive or Rare Species

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

Black Fly Biology

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

Female black flies generally ambush their victims from tree-top perches near the edge of an open area and are active during the day; peak activity is in the morning and early evening. Females live from one to three weeks, depending on species and weather conditions. They survive best in cool, wet weather. Studies 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 horse and cattle.

Reference Cited

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

Harris, M.C., Dotseth, E.J., Jackson, B.T., Zink, S.D., Marek, P.E., Kramer, L.D., Paulson, S.L., and D.M. Hawley. 2015. La Crosse virus in *Aedes japonicus japonicus* mosquitoes in the Appalachian region, United States. Emerging Infectious Diseases. 21(4): 646-649.

Species Code and Significance/Occurrence of the Mosquitoes in MMCD

Code	Genus	species	Significance/ Occurrence	Code	Genus	species	Significance/ Occurrence
Mosquitoes							
1.	*Aedes*	*abserratus*	common, spring	27.	*Anopheles*	*barberi*	rare, tree hole
2.		*atropalpus*	rare, summer	28.		*earlei*	uncommon/rare
3.		*aurifer*	rare, spring	29.		*punctipennis*	common
4.		*euedes*	rare, spring	30.		*quadrimaculatus*	common
5.		*campestris*	rare, spring	31.		*walkeri*	common
6.		*canadensis*	common, spring-summer	311.	*An*. unidentifiable		
7.		*cinereus*	common, spring-summer				
8.		*communis*	rare, spring	32.	*Culex*	*erraticus*	rare
9.		*diantaeus*	rare, spring	33.		*pipiens*	common
10.		*dorsalis*	common, spring-summer	34.		*restuans*	common
11.		*excrucians*	common, spring	35.		*salinarius*	uncommon
12.		*fitchii*	common, spring	36.		*tarsalis*	common
13.		*flavescens*	rare, spring	37.		*territans*	common
14.		*implicatus*	uncommon, spring	371.	*Cx*. unidentifiable		
15.		*intrudens*	rare, spring	372.	*Cx.*	*pipiens/restuans*	when inseparable
16.		*nigromaculis*	uncommon, summer				
17.		*pionips*	rare, spring, northern MN spp.	38.	*Culiseta*	*inornata*	common
18.		*punctor*	common, spring	39.		*melanura*	uncommon, EEE
19.		*riparius*	common, spring	40.		*minnesotae*	common
20.		*spencerii*	uncommon, spring	41.		*morsitans*	uncommon
21.		*sticticus*	common, spring-summer	411.	*Cs*. unidentifiable		
22.		*stimulans*	common, spring	42.	*Coquillettidia*	*perturbans*	common
23.		*provocans*	common, early spring	43.	*Orthopodomyia*	*signifera*	rare
24.		*triseriatus*	common, summer, LAC vector	44.	*Psorophora*	*ciliata*	rare
25.		*trivittatus*	common, summer	45.		*columbiae*	rare
26.		*vexans*	common, #1 summer species	46.		*ferox*	uncommon
50.		*hendersoni*	uncommon, summer	47.		*horrida*	uncommon
51.		*albopictus*	rare, exotic, Asian tiger mosquito	471.	*Ps*. unidentifiable		
52.		*japonicus*	summer, Asian rock pool mosq.				
53.		*cataphylla**		48.	*Uranotaenia*	*sapphirina*	common, summer
118.		*abserratus/punctor*	inseparable when rubbed	49.	*Wyeomyia*	*smithii*	rare
261.	*Ae.* unidentifiable			491.	Males		
262.	Spring *Aedes* (adult samples only)			501.	Unidentifiable mosquito		
263.	Non-*vexans Aedes* (larval airwork)			601.	Non-mosquito insect (ex. phantom midge)		
264.	Summer *Aedes* (adult samples only)						

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

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

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

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

*treated only at select sites as determined by MNDNR permit

APPENDIX B Average Number of Common Mosquitoes Collected per Night in Four Long-term NJ Light Trap Locations and Average May to September Rainfall, 1965-2021. Trap 1, Trap 9, Trap 13, and Trap 16 have run yearly since 1965. Trap 1 was discontinued in 2015.

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

Continued on next page

Year	Spring *Aedes*	*Aedes cinereus*	*Aedes sticticus*	*Aedes trivittatus*	*Aedes vexans*	*Culex tarsalis*	*Cq. perturbans*	All species	Avg. Rainfall
2006	0.05	0.08	0.14	0.01	6.73	0.08	1.85	10.04	18.65
2007	0.22	0.27	0.01	0.01	8.64	0.26	0.94	13.20	17.83
2008	0.38	0.32	0.17	0.01	8.17	0.10	2.01	12.93	14.15
2009	0.10	0.07	0.00	0.02	3.48	0.04	0.23	4.85	13.89
2010	0.07	0.08	0.06	0.17	16.18	0.23	0.36	26.13	24.66
2011	0.10	0.07	0.11	0.78	33.40	0.07	5.76	47.36	20.61
2012	0.04	0.03	0.15	0.21	21.10	0.04	4.01	30.39	17.53
2013	0.37	0.49	0.15	0.81	26.95	0.12	1.80	35.08	17.77
2014	0.12	0.32	0.19	0.44	32.42	0.20	2.18	41.72	23.60
2015*	0.02	0.26	0.01	0.46	27.73	0.06	3.77	36.00	24.02
2016	0.01	0.03	0.01	1.65	24.53	0.06	4.80	33.44	27.76
2017	0.01	0.08	0.09	0.17	25.71	0.05	9.62	37.85	22.27
2018	0.02	0.04	0.18	0.26	15.21	0.05	1.88	20.76	22.54
2019	0.02	0.03	0.03	0.19	5.86	0.02	0.89	8.27	26.67
2020	0.09	0.05	0.12	0.21	10.52	0.01	3.88	16.49	20.00
2021**									15.43

*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.
**Samples are currently being processed

APPENDIX C Description of Control Materials Used by MMCD in 2021

The following is an explanation of the control materials currently used by MMCD. The specific names of products used in 2020 are given. The generic products will not change in 2021, although the specific formulator may change.

Insect Growth Regulators

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

Altosid® briquets are typically applied to mosquito oviposition sites that are three acres or less. Briquets are applied to the lowest part of the site on a grid pattern of 14-16 ft apart at 220 briquets per acre. Sites that may flood and then dry up are treated completely. Sites that are somewhat permanent are treated with briquets to the perimeter of the site in the grassy areas. Pockety ground sites (i.e., sites without a dish type bottom) may not be treated with briquets due to spotty control achieved in the uneven drawdown of the site. *Coquillettidia perturbans* sites are treated at 330 briquets per acre in rooted sites or 440 briquets per acre in floating cattail stands. Applications are made in the winter and early spring.

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

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

Methoprene granules Central Life Sciences
Altosid® P35 EPA# 89459-95

Altosid® P35 consist of methoprene formulated in spherical granule. Altosid® P35 is designed to provide up to 30 days control but trials have indicated control up to 40 days. Applications will be made to ground sites (less than three acres in size) at a rate of 2.5 lb per acre for *Aedes* control and 3-5 lb per acre for *Cq. perturbans* control. Applications will also be done by helicopter in sites that are greater than three acres in size at the same rate as ground sites, primarily for *Cq. perturbans* control.

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

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

Bacterial Larvicides

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

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

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

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

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

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

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

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

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

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

Pyrethrin Adulticides

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

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

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

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

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

Pyrethroid Adulticides

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

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

Permethrin Clarke
Permethrin 57% OS EPA# 8329-44

Permethrin 57% OS is used by the District to treat adult mosquitoes in known daytime resting or harborage areas. Harborage areas are defined as wooded areas with good ground cover to provide a shaded, moist area for mosquitoes to rest during the daylight hours. The material is diluted with soybean and food grade mineral oil (1:10) and is applied to wooded areas with a power backpack mister at a rate of 25 oz of mixed material per acre (0.0977 lb AI per acre).

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

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

APPENDIX D 2021 Control Materials: Active Ingredient (AI) Identity, Percent AI, Per Acre Dosage, AI Applied Per Acre and Field Life

Material	AI	Percent AI	Per acre dosage	AI per acre (lb)	Field life (days)
Altosid® briquets [a]	Methoprene	2.10	220	0.4481	150
			330	0.6722	150
			440	0.8963	150
			1*	0.0020*	150
Altosid® pellets	Methoprene	4.25	2.5 lb	0.1063	30
			4 lb	0.1700	30
			0.0077 lb* (3.5 g)	0.0003*	30
Altosid® P35	Methoprene	4.25	2.5 lb	0.1063	30
			3 lb	0.1276	30
			0.0077 lb* (3.5 g)	0.0003*	30
MetaLarv® S-PT	Methoprene	4.25	2.5 lb	0.1063	30
			3 lb	0.1275	30
			4 lb	0.1700	30
Natular® G30	Spinosad	2.50	5 lb	0.1250	30
VectoBac® G	*Bti*	0.20	5 lb	0.0100	1
			8 lb	0.0160	1
VectoLex® FG	*Bs*	7.50	8 lb	0.6000	7-28
			15 lb	1.1250	7-28
			0.044 lb* (20 g)	0.0034*	7-28
VectoLex® WSP***	*Bs*	7.50	0.022 lb** (10 g)	0.0017**	7-28
VectoPrime® FG***	*Bti* and methoprene	6.07 *Bti* 0.10 methoprene	4 lb	0.2428 *Bti* 0.0040 methoprene	7 single flood
Permethrin 57%OS [b]	Permethrin	5.70	25 fl oz	0.0977	5
Zenivex® E4 [c]	Etofenprox	4.00	1.0 fl oz	0.0023	<1
Anvil® [d]	Sumithrin	2.00	3.0 fl oz	0.0035	<1
Pyrocide® [e]	Pyrethrins	2.50	1.5 fl oz	0.00217	<1
Merus™ [f]***	Pyrethrins	5.00	1.5 fl oz	0.0048	<1

[a] 44 g per briquet total weight (220 briquets=21.34 lb total weight)
[b] 0.50 lb AI per 128 fl oz (1 gal) (product diluted 1:10 before application, undiluted product contains 5.0 lb AI per 128 fl oz)
[c] 0.30 lb AI per 128 fl oz (1 gal)
[d] 0.15 lb AI per 128 fl oz (1 gal)
[e] 0.185 lb AI per 128 fl oz (1 gal)(product diluted 1:1 before application, undiluted product contains 0.37 lb AI per 128 fl oz)
[f] 0.4096 lb AI per 128 fl oz (1 gal)
* Catch basin treatments—dosage is the amount of product per catch basin.
** Catch basin treatments—dosage is the amount of product per pouch, catch basins can be treated with one or two pouches.
***Experimental

APPENDIX E Acres Treated with Control Materials Used by MMCD for Mosquito and Black Fly Control, 2013-2021.The actual geographic area treated is smaller because some sites are treated more than once

Control Material	2013	2014	2015	2016	2017	2018	2019	2020	2021
Larvicides									
Altosid® XR Briquet 150-day	189	193	186	168	166	167	162	180	141
Altosid® XRG	6,948	52	0	0	0	0	0	0	0
Altosid® Pellets 30-day	15,813	26,179	31,494	19,173	17,939	10,202	12,020	729	0.16
Altosid® Pellets catch basins (count)	246,300	239,829	248,599	240,806	252,694	262,851	265,915	264,399	13,550
Altosid® P35 30-day	0	0	0	0	0	0	0	26,784	26,511
Altosid® P35 Catch basins (count)	0	0	0	0	0	0	0	11,648	270,810
MetaLarv™ S-PT	14,063	18,073	21,126	33,409	23,740	23,574	23,003	18,408	19,431
Natular® G30	15,000	14,950	8,840	13,023	12,271	15,662	17,277	8,946	19,968
Altosid® XR Briquet catch basins (count)	375	437	450	448	445	509	476	470	414
VectoLex® FG granules	2,330	3,064	3,777	6,076	4,773	4,660	5,036	1,858	5,255
VectoBac® G *Bti* corn cob granules	150,280	255,916	258,148	234,120	136,173	134,926	156,089	139,006	78,992
VectoBac® 12 AS *Bti* liquid (gal used) Black fly control	3,878	4,349	4,351	3,112	3,621	3,234	4,362	4,085	1,172
Adulticides									
Permethrin 57% OS Permethrin	9,020	8,887	6,093	8,128	5,038	3,771	3,367	1,742	113
Scourge® 4+12 Resmethrin/PBO	37,204	44,890	19,767	23,072	2,090	0	0	0	0
Anvil® 2 + 2 Sumithrin/PBO	36,000	31,381	27,183	16,399	11,683	7,790	3,665	584	257
Pyrocide® Adulticide	0	5,338	3,605	0	0	0	0	0	0
Zenivex® Etofenprox	0	0	10,380	34,984	23,097	26,918	15,289	4,124	2,166

APPENDIX F Graphs of Larvicide, Adulticide, and ULV Fog Treatment Acres, 1984-2021

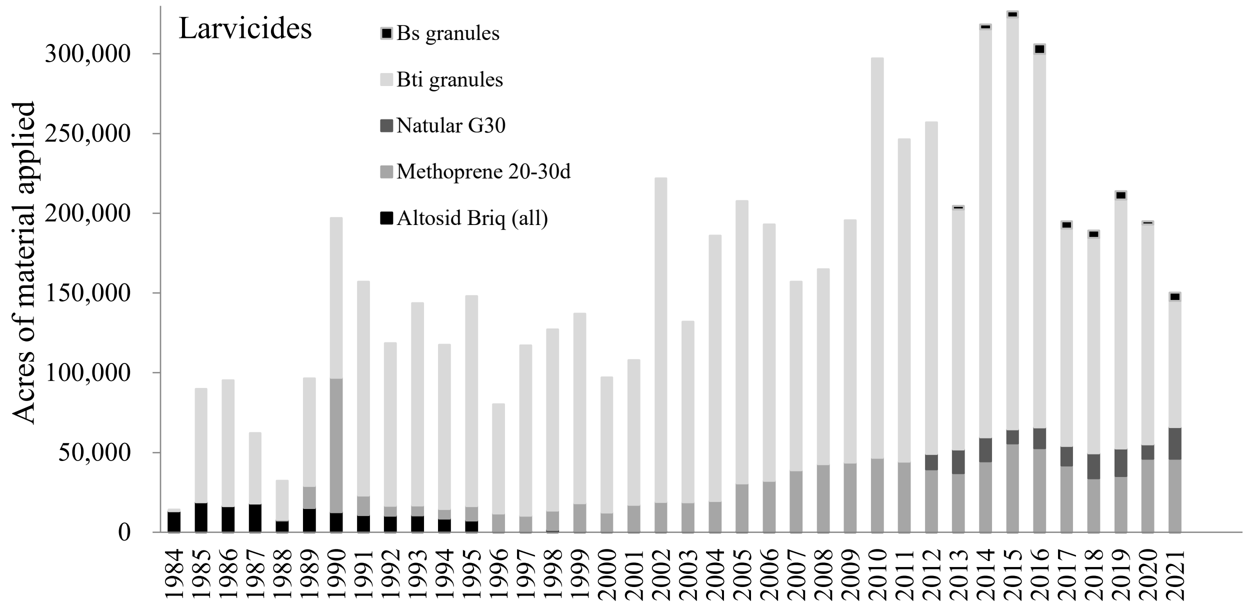


Figure F.1 Summary of total acres of larvicide treatments applied per year since 1984. For materials that are applied to the same site more than once per year, actual geographic acreage treated is less than that shown.

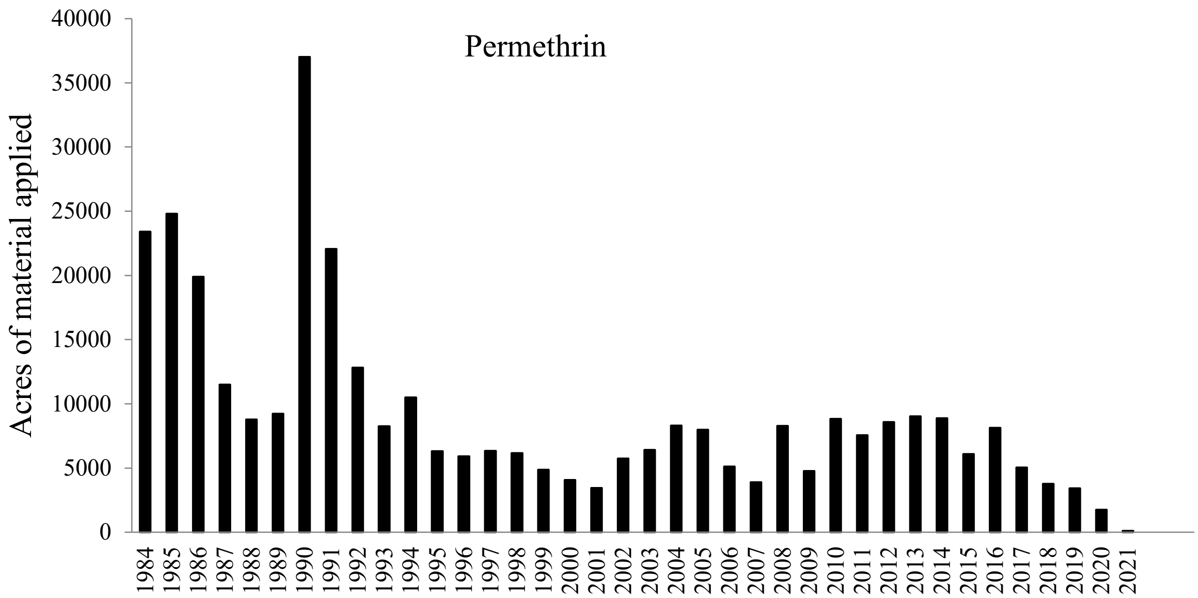


Figure F.2 Summary of total acres of permethrin treatments applied per year since 1984. This material may be applied to the same site more than once per year, so actual geographic acreage treated is less than that shown.

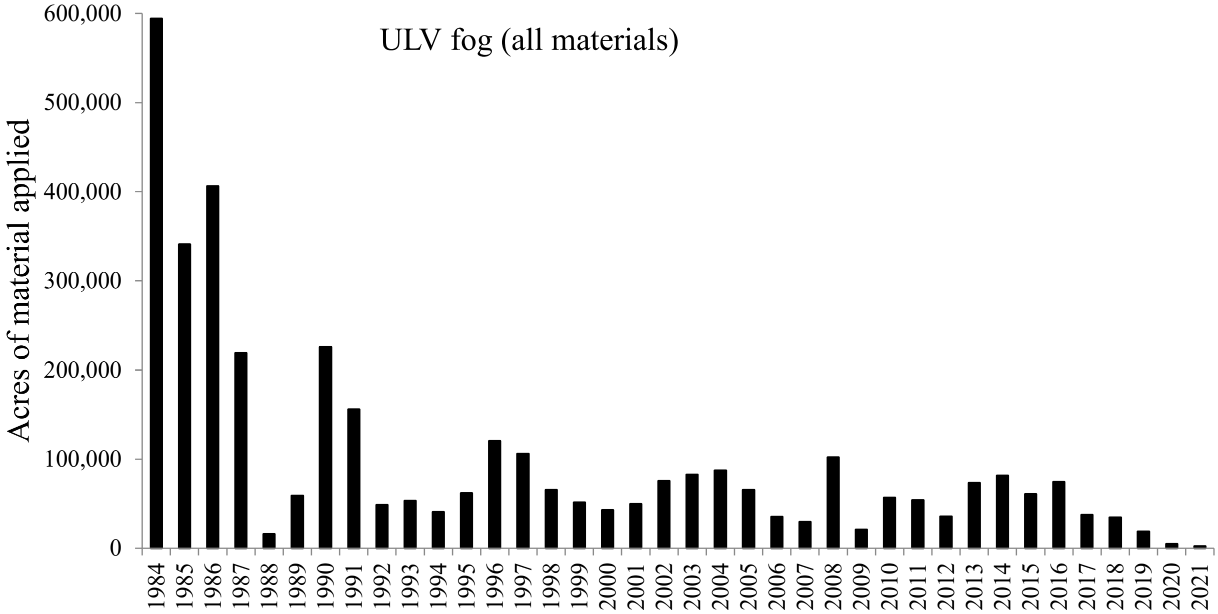


Figure F.3 Summary of total acres of ULV fog treatments applied per year since 1984. This material may be applied to the same site more than once per year, so actual geographic acreage treated is less than that shown.

Our Mission

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

Our Vision

To be the leading mosquito abatement district in the world

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

Our Values

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

mmcd
METROPOLITAN MOSQUITO CONTROL DISTRICT

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