FRASER VALLEY REGIONAL DISTRICT MOSQUITO CONTROL PROGRAM 2020 YEAR-END REPORT

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Executive Summary

Morrow BioScience Ltd. (MBL) has now completed the second year of a five-year contract as mosquito control contractor for the Fraser Valley Regional District (FVRD). This is the 17th consecutive year providing floodwater mosquito control for the FVRD. The mosquito control program reduces floodwater mosquito abundance within all areas of the FVRD. Most control activity takes place along and within the Fraser River from Hope to Abbotsford/Mission.

The snowpack in basins contributing to the Fraser River were considerably high leading into the 2020 floodwater mosquito season. A warming trend in late May within contributing snow basins led to most of the low elevation and some middle elevation snowmelt. This snowmelt resulted in the initial peak of the Lower Fraser River at the Mission gauge (June 5; 5.39 m). Unstable weather in River-associated snow basins occurred from early to mid-June. A secondary warming trend within contributing snow basins occurred from mid to late-June, resulting in residual middle elevation and high-elevation snowpack depletion. This warming trend also led to the official peak of the Lower Fraser River on June 30 (5.91 m). The 2020 Lower Fraser River peak occurred approximately 2-3 weeks later than normal, was nearly 1 m higher than the 19-year average, and was higher than 3 m for a record-setting 95 days. The Fraser River also rose relatively slowly and peaked when local ambient temperatures and local precipitation accumulation were high. All of these factors contributed to high larval abundance in 2020.

Between May 5 and August 17, a total of 2,446 hectares was treated by ground and helicopter. A total of 13 aerial treatment days were required this season, with two larger campaigns (i.e., Fraser Valley-wide treatments) divided over numerous days due to weather delays. Total treated area in 2020 is the most area treated since prior to 2009, at least. Treatment efficacy was assessed as high and no known sites were missed. However, MBL staff were not able to accompany helicopter pilots during aerial treatments due to COVID-19 restrictions. Thus, it's possible areas of the Fraser River islands were not treated as thoroughly as usual. In the future, GIS treatment layers will be provided to the helicopter company prior to aerial campaigns, if MBL staff members are unable to accompany. A real-time monitoring and treatment data dashboard was again provided to the FVRD program manager. The dashboard enables managers to view up-to-date treatment information and ensure quality control.

Adult mosquito trapping revealed a total of 365 specimens over 56 trap nights at historically established locations throughout the FVRD. The high adult trap volume may be a function of increased trapping effort (i.e., more than twice the average number of trap nights), the sustained high Fraser River levels, and a compound number of mosquito eggs hatching in 2020. Regional adult mosquito species identification revealed a high percent composition of floodwater *Aedes* species and *Coquillettidia perturbans*, which reflect increased floodwater and emergent vegetation mosquito development habitat available in 2020. Accordingly, concern call volume was also higher than average, totaling 130. Five concern emails were received. The majority of calls and emails were received 2-3 weeks

following the initial peak of the Fraser River in early June. All calls and emails were returned within 24 hours.

Communications with in-program First Nations bands and residents remains a priority for MBL. COVID-19 gathering restrictions reduced the potential for in-person education outreach and volunteer events. As a substitute, MBL added information pamphlets and blogs available through the MBL website (www.morrowbioscience.com) and also directly from the FVRD. MBL staff provided a total of five (5) interviews to local newspapers and television news outlets. Interviews focused on the seasonal outlook, mosquito biology, and tips for personal protection. The reach of social media posts continues to increase annually, meaning that more residents around the FVRD are aware of mosquito abatement efforts.

Season Highlights

- The snowpack in basins contributing to the Fraser River ranged from 97-147 % of normal in April, immediately preceding the onset of the mosquito season.
- The Lower Fraser River freshet and local precipitation created a bi-modal appearance to river levels in 2020.
- A region-wide warming event within contributing basins prompted considerable low and mid-elevation snow melt conditions in late May, resulting in the initial peak of the Fraser River (June 5; 5.39 m).
- A higher secondary peak occurred on June 30 (5.91 m) in response to regional warming events in the second half of June.
- The peak was the highest since 2018 and occurred 2-3 weeks later-than-average.
- Thirteen (13) aerial treatments were required throughout the FVRD region in 2020. Events ranged from May 15 – July 5 and were clustered around the two prominent freshet-influenced peaks in 2020.
- Liquid and granular Aquabac® (a.i., *Bacillus thuringiensis* var. *israelensis)* treatments occurred in 2020, with liquid treatments being conducted solely at Stave Lake.
- Combined, ground and aerial Aquabac® treatments totalled 19,935 kg granular Aquabac® and 70,000 ml liquid Aquabac®.
- Total area treated was 2,446 ha; the 2020 total treated area is approximately 590 ha greater than that treated in 2018, another high-water year.
- Adult traps were set on 56 nights, collecting 365 adult specimens.
- Another set of adult mosquito specimens from 11 trap locations (i.e., 56 trap nights, 486 specimens) were collected at regional sites outside of the FVRD. Inferences based on those species composition results will be used to understand the FVRD adult mosquito population.
- *Aedes* species accounted for 53.9%, over-all.
- *Coquillettidia perturbans* accounted for 26%, over-all.
- *Culex* species only accounted for 6%, over-all.
- *Aedes japonicus* was identified from an adult mosquito trap located in the City of Coquitlam. The specimen was also independently verified and reported to the Director of the Entomological Society of BC at the University of British Columbia

- Mosquito hotline concern call volume was 130, which may be representative of the high water year, sustained high water, and a compound number of mosquito eggs.
- Five emails were received.
- MBL's real-time data management and mapping portal provided MBL managers with improved ability to target areas and gave quality control assurance for clients.
- Education outreach was focused entirely online through social media, additional Frequently Asked Question documents for *Bacillus thuringiensis* var. *israelensis*, mosquito biology, and COVID-19.
- The MBL Operations Manager provided interviews to CTV (July 3), Global News (July 10), Mission City Record (July 14), and The Chilliwack Progress (July 15).
- No human cases of West Nile virus or Zika virus were reported in BC.
- Relatively few West Nile virus cases (humans, horses, mosquito pools) were reported in Washington and Idaho states; all infections were reported in the southern half of both states.

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Introduction

Morrow BioScience Ltd. (MBL) is the longest-operating mosquito control firm in British Columbia, having conducted mosquito control in this province for nearly four decades. MBL has been the mosquito control provider for the Fraser Valley Regional District (FVRD) since 2004. A 5-year contract was re-established in 2019; the 2020 mosquito season marked MBL's 2nd year within the new term.

The FVRD contains a large spatial area of mosquito development sites, considerable habitat variation, and the largest river in BC. These variables make the FVRD mosquito control program particularly complex. Within the previous 17 years, MBL staff has acquired thorough knowledge of the program regarding site locations and effective treatment timing. Numerous improvements have been made to the program since its inception, including: Fraser River island site survey and site addition, the addition of a real-time data collection and review portal, increased public engagement both through social media and through in-person events, and improved environmental awareness through annual carbon offset purchases. MBL's goal is to continue to provide effective mosquito control to the FVRD residents, while remaining socially and environmentally responsible.

Carbon Offsets

The spatial reach and scope of the FVRD mosquito program is such that driving is an inevitable requirement. The accumulated mileage over the course of 2020 was approximately 32,800 km (ground transportation only).

As an estimation, the driving requirements for this program result in the production of approximately 8.9 tonnes of CO_2 emissions. To offset this addition of CO_2 to the environment, MBL has committed to purchasing carbon offsets. To fulfill this commitment, carbon offsets are purchased through the West Kootenay EcoSociety[1]. When the carbon offsets are purchased, a proof of purchase and certificate from the offset provider will be delivered to the FVRD.

Methodology

Floodwater mosquito larvae are the primary target of the FVRD mosquito program. Female floodwater mosquitoes (e.g. *Ae. vexans*, *Ae. sticticus*) deposit their eggs on damp substrate along the Fraser River corridor. When the high water caused by the freshet and/or significant localized precipitation floods these areas in the spring, the result is large-scale mosquito egg hatching. If numerous seasons have passed between high-water years, then high river levels may produce a compound number of mosquito larvae. While study results vary, Breeland and Pickard (1967) estimate that *Aedes vexans* eggs can remain viable for up to four (4) years while they await necessary hatching cues.

[1] https://www.ecosociety.ca

MBL field technicians begin monitoring all known mosquito development sites within the FVRD prior to rising Fraser River levels in the spring (Image 1). When Fraser River levels start rising, monitoring efforts increase. Communication with the public assists staff in locating new sites, as well as acquiring historical knowledge of the program area.

Image 1. MBL field technician checking dipper for mosquito larvae

Larval mosquitoes in sufficient number (i.e. >4/dip) are treated by ground applications of the microbial larvicide, Aquabac®. This product has the active ingredient *Bacillus thuringiensis israelensis* (Bti). In 2020, the granular and liquid formulations of Aquabac® were used. The granular form is carried on a corncob mixture and the liquid form is water-based. The mode of action for Bti is the same for both formulations. The mode of action for Bti is relatively simple and with a high degree of species specificity. Receptors within the mid-gut region of the mosquito larvae are specific to the toxin proteins that are produced alongside each bacterial spore. After the mosquito larvae ingest the toxin protein, disruption of the larval mid-gut cells occurs. This event causes considerable damage to the wall of the mosquito larvae's gut and quickly leads to larval death (Boisvert and Boisvert 2000).

As the season progresses and more mosquito development sites become flooded, it is increasingly difficult to treat sites by ground due to inaccessibility and concurrent site activation. At this point, a helicopter is used to conduct aerial treatments. The aerial campaign uses the same pesticide as ground applications, although typically with a higher application rate to permeate canopy cover. Aerial treatments take approximately two days per campaign, due mostly to the level of flooding involvement on the Fraser River islands. In 2020 aerial campaigns (i.e., large-scale treatment of the Fraser Valley and Fraser River Islands) were broken up in 2, 3, and 5 day periods due to weather-related delays.

It is important to time treatments according to the correct stage of larval development (3rd and 4th instar). If treatments are applied too early, the larvae will not have reached their highest feeding rate yet and if applied too late, the larvae molt into pupae (i.e. non-feeding stage). Both circumstances may result in the development of adult mosquitoes. Additionally, by waiting until mosquito larvae are in the 3rd and early 4th instar stages, early instar larvae are available as food sources in their ecosystem.

When flooding commences and ambient temperatures rise, many standard dips easily exceed the treatment threshold. Larval densities within the range of 200-500 per dip (observed as high as 1,000 per dip) are commonly detected. All sites are checked within one or two days of the initial treatment to ensure treatment efficacy. Efficacy assessments at sites treated aerially are typically conducted by boat or canoe. If sites are unsafe to access by either of those methods, then representative sites are selected to assess efficacy. Touchups are conducted, as required. Anecdotal field results from the previous 17 seasons show that efficacy is between 85-95 percent.

Environmental Conditions

The three main environmental conditions that affect the Fraser River levels throughout the mosquito season (e.g. April – July) are: 1) the snowpack in snow basins contributing to the Fraser River, 2) ambient temperature in snow basins contributing to the Fraser River, and 3) local precipitation. Local ambient temperature is also of interest due primarily to how local ambient temperature affects mosquito egg hatching and larval development rates. As such, all noted conditions are tracked throughout the season.

Snowpack

Floodwater mosquito abundance within the FVRD is primarily influenced by regional Fraser River water levels. In turn, the water levels of that system are largely dictated by the freshet released from the Fraser, Thompson, and Nechako Plateaus between April and July (Image 2). The Fraser River is also influenced by tidal variations and high, spatially concentrated precipitation accumulation, although to a lesser degree. When snowpacks exceed 100 percent of normal and when regional precipitation accumulation is above normal, higher Fraser River levels are expected during the mosquito season.

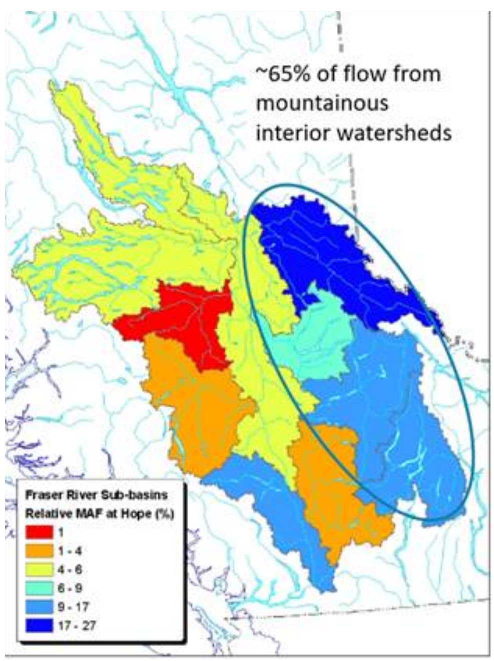


Image 2. Fraser River sub-basin freshet contribution (A. Jollymore; River Forecast Centre)

In April, immediately preceding the 2020 mosquito monitoring season, the basins influencing the Fraser River freshet ranged from 97 – 147 percent of normal (Table 1). Cool and dry weather within influential basins throughout April resulted in comparably little snowmelt over the month. While an initial snowmelt was observed in most basins in early-May, unstable weather patterns from April through mid-May also resulted in considerable late-season snow accumulation.

Table 1. Snow basin indices (2012-2018 average, 2020) for basins that directly affect the Lower Fraser River flood plain, determined by the 1 April 2020 Snow Survey and Water Supply Bulletin. Values reported are considered percent of normal.

Basin	Average April Snowpack (2012-2018)	2020 April Snowpack
Upper Fraser East	109	147
Upper Fraser West	117	129
Lower Fraser	97	97
Middle Fraser	99	111
North Thompson	104	117
South Thompson	106	123
Nechako	102	101

A longer and more intense warming event occurred at the end of May within influential basins. This warming event caused most low and some middle-elevation snowpack to melt. For the most part, basins were depleted of remnant middle elevation and high-elevation snowpack following a warming event in the second half of June. However, the residual high-elevation snowpack within the Upper Fraser East basin wasn't depleted until mid-July.

In general, the snowpack remained within influential basins for 2-4 weeks beyond normal. Data from the final Snow Survey and Water Supply Bulletin from June 15[2] highlighted the anomaly of the snowpack persistence in 2020. The percent of normal snowpack was still exceeding 100 percent in over half of the contributing basins (Table 2). In fact, four of the six basins showed higher values in 2020 than in 2018, another high-water year (Table 2). While the River Forecast Centre suggested cautious interpretation of the reported percentages, the considerably high 'percent of normal' snowpack remaining as of 15 June reflected the rarity in late-season snowpack persistence.

Table 2. Snow basin indices for basins that directly affect the Lower Fraser River flood plain, determined by the June 15 (2018, 2019, 2020) bulletins. (https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/drought-flooding-dikes-dams/river-forecast-centre/snow-survey-water-supply-bulletin).

	Percent of Normal Snowpack		
Basin	2018	2019	2020
Upper Fraser East	12	44	229
Upper Fraser West	No data	No data	No data
Middle Fraser	18	18	122
Lower Fraser	73	3	59
North Thompson	38	31	138
South Thompson	97	19	129

[2] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/river-forecast/2020_june15_v10.pdf

Nechako	20	0	0

Given 2020 snow station report figures, the majority of the 2020 Fraser River freshet ostensibly lasted from early May through early July[3]. Within that time, the freshet was exacerbated by stints of high regional precipitation accumulation in May and June (see 'Local Precipitation' below). The effect of these two variables resulted in high water within the Lower Fraser River persisting for a significantly longer period than normal.

Local Precipitation

Significant temporally and spatially concentrated precipitation accumulation may elevate Fraser River levels. Local precipitation can also temporarily increase seepage site levels, where considerable mosquito development habitat is located. Thus, tracking local precipitation accumulation can aid MBL field staff with determining how long mosquito development sites may require management. The Mission West Abbey weather station (ID: 1105192) provides both historical precipitation accumulation averages (i.e.1981 – 2020) and also current-year totals, allowing for the comparison of current-year environmental conditions with historical conditions. This comparison allows for some level of prediction regarding larval mosquito development rate and treatment timing requirements.

Precipitation received to the Mission West Abby weather station in April was markedly lower than normal (Figure 1). This is consistent with the documented few unstable weather systems in April, despite cooler temperatures. Precipitation received to the area within May and June was greater than average (Figure 1). Thus, precipitation in these months likely augmented rising Fraser River levels and associated seepage sites. Precipitation events during May and June also caused some delays in aerial campaigns, such that campaigns needed to be divided between multiple days.

Precipitation accumulation in July 2020 was less than half of that received in the previous month. Specifically, precipitation received in July was only 67 mm (Figure 1). However, 68 percent of the precipitation received in July occurred from the 1st – 3rd while Fraser River levels were still showing signs of a late-season freshet. Thus, the precipitation received to the area within the first few days of July, likely compounded a peaking Fraser River at Mission (see 'River Levels' below). The relatively low amount of precipitation received in the latter portion of July was of little consequence to the regional Fraser River levels and associated mosquito development sites.

[3] https://governmentofbc.maps.arcgis.com/apps/webappviewer/index.html?id=c15768bf73494f5da04b1aac6793bd2e

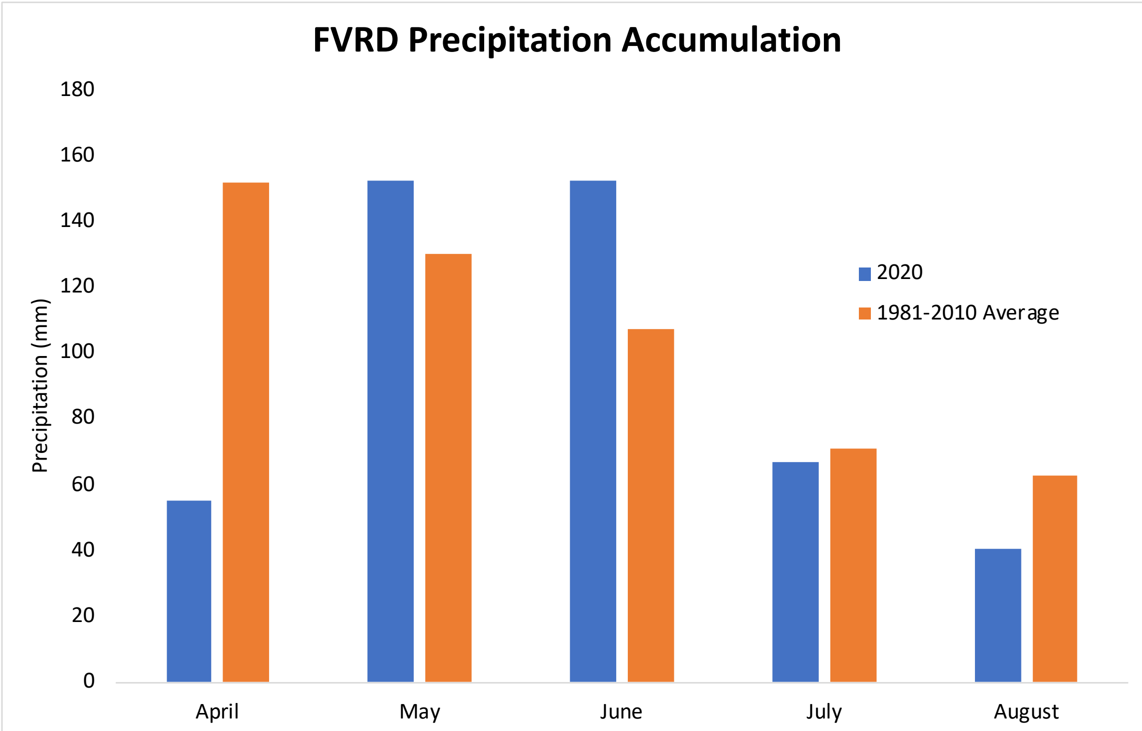


Figure 1. 2020 precipitation values (rainfall and snow accumulation; mm) recorded at the Mission West Abby Station (ID: 1105192) for 01 April – 31 August (blue) and average station precipitation values (1981-2010; orange).

August precipitation accumulation was approximately 40 mm and more than 20 mm less than the average accumulation for that month (Figure 1). Given these data, it is reasonable to determine that local precipitation did not measurably augment regional Fraser River levels in August. By August the Fraser River and associated seepage site levels had receded below the threshold for mosquito egg hatching, and thus the low precipitation accumulation in August didn't impact late-season mosquito larval hatching. However, it's possible that precipitation received in August created habitat for container mosquito breeding. Thus, adult mosquito presence toward the end of the season was likely due to container mosquito hatches, not floodwater species.

Ambient Temperature

Ambient temperature, both locally and within the contributing snow basins, is an important variable to track. From April through August, local ambient temperature fluctuations can affect mosquito egg hatching, larval development rate, adult dispersal, and adult survival. Ambient temperature within contributing snow basins dictates the commencement and sometimes the concentration of the freshet.

Across the snow basins most influencing the Fraser River freshet, the 2020 mosquito season began in April with below-normal temperatures. The May 1st Snow Survey and Water Supply Bulletin[4] noted that temperature anomalies across most of the province were generally from 0ºC to -2ºC. A small amount of snowmelt occurred in Fraser River-

[4] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/river-forecast/2020_may1.pdf

associated basins in April, but the generally cooler weather in April resulted in a delay of the freshet by approximately 2 weeks.

Although ambient temperatures in May within Fraser River-associated snow basins was comparatively higher than those recorded in April, they were still considered cooler-than-average in the middle of the month. A ridge of high pressure within those basins in later May led to the majority of low and some mid-elevation snowmelt. The late-May higher ambient temperatures experienced within contributing basins would eventually lead to the initial peak of the Fraser River at Mission (i.e. June 5; 5.39 m).

Ambient temperature within much of the Province during the first half of June was dominated by low-pressure systems. The low-pressure systems were cooler within Fraser River-associated basins and further slowed the residual high elevations snow from coming out. A more consistent warming trend in mid-June caused the remaining snowmelt to accelerate, resulting in the official peak in the Fraser River at Mission (i.e. June 30, 5.91 m). Temperature data are consistent with 2020 automated snow station data[5] depicting snowmelt points correlating with regional ambient temperature spikes.

If the ground proximate to the Fraser River contains floodwater mosquito eggs and if hatching conditions are present (i.e. low dissolved oxygen, higher ambient temperatures), then mosquito egg hatching will commence (Mohammad and Chadee 2011). Thus, local ambient temperature is a predictive tool when gauging floodwater egg hatch commencement. Local ambient temperature data are acquired from the Mission West Abbey weather station (ID: 1105192).

To illustrate the effect of ambient temperature on mosquito hatching, Trpis and Horsfall (1969) exposed submerged eggs of a common univoltine floodwater mosquito species, *Aedes sticticus*, to various constant air temperatures and recorded hatching success. Results revealed that eggs began to hatch at 8°C, although larval development was slow and survivorship was low. Eggs held at 21°C provided the optimal temperature, of the five temperatures tested, for hatching and larval development (Figure 2). While *Ae. sticticus* is not the sole floodwater species present in the FVRD, it serves as a representative species for our purposes and provides general developmental benchmarks.

[5] https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-science-data/water-data-tools/snow-survey-data/automated-snow-weather-station-data

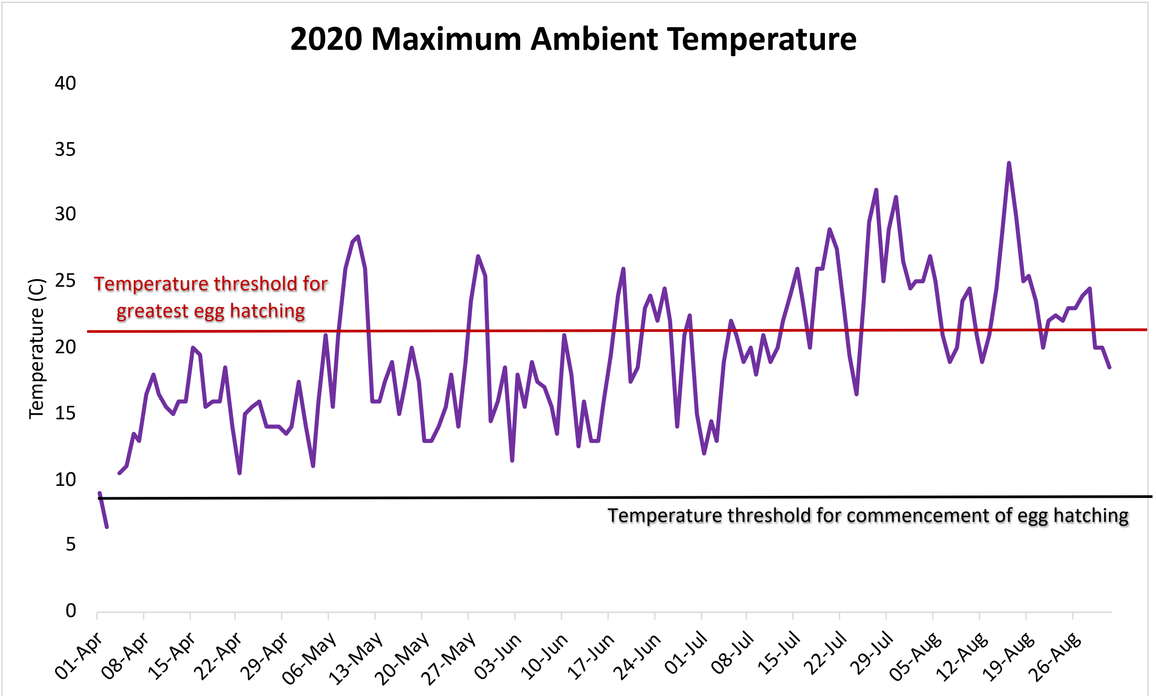


Figure 2. Maximum daily ambient temperatures (C) as recorded at the Mission West Abby Station (ID: 1105192) 01 April – 31 August 2020. Lower black line illustrates threshold at which *Ae. sticticus* eggs commence hatching; upper red line illustrates threshold at which most *Ae. sticticus* eggs hatch.

Within the FVRD, the 2020 season began with higher-than-normal ambient temperatures for April. The monthly average for April (14.6 °C) was 1°C higher than the station average for April. Thus, floodwater mosquito eggs within the FVRD were likely activated within April if exposed to flooding conditions (Figure 2). However, the larval development at cooler temperatures would have been notably slow (Trpis and Horsfall 1969). The potential for larval development – even in the early portion of the mosquito season – is the primary reason for site monitoring commencement in April.

Local ambient temperatures in May were relatively warmer and closer to those most favourable larval development conditions (Figure 2). Specifically, the average maximum daily temperature for May was 2°C higher than average at 18.6°C. Mosquito egg hatching and larval development rates increased significantly in May, with larval treatments required starting in early May.

Ambient temperatures in June were generally higher than May temperatures, although still lower than average. A warming trend toward late June facilitated further mosquito hatching and increased larval development rates. Because considerable floodwater development sites were at peak levels, the need to treat mosquito larvae in June was directly correlated with ambient temperature.

As predicted by the Temperature and Precipitation Probabilistic Forecasts for Canada, July and August ambient temperatures were higher than average. The combination of peak regional Fraser River levels and high ambient temperatures resulted in ground and aerial treatments continuing into July (see ‘Larval Control’ section). By August, regional Fraser River levels were receding and ambient temperature was no longer directly related to floodwater larval mosquito abundance. However, ambient temperature does increase development rates for larval and adult mosquitoes (Ciota et al. 2014). Thus, any floodwater mosquitoes that successfully emerged would have had a reduced lifespan with the heightened ambient temperatures into late August (Figure 2).

Localized mosquito annoyance due to container mosquito presence occurred in July and through August. Container mosquito habitats near residential homes can be created throughout the summer whenever the presence of water is coupled with high ambient temperatures. Thus, ambient temperature more directly affects container mosquito production in July and August. MBL technicians regularly inform residents that adult container-bred mosquitoes can be reduced around homes by ensuring container mosquito environments are either free of water or refreshed frequently.

River Levels

Within the FVRD, the majority of floodwater mosquito development sites are found along the flooding corridors of the Fraser River and associated seepage sites. As the presence of water is the prime hatching cue for floodwater mosquito eggs, springtime Fraser River levels provide predictions about the extent of floodwater mosquito egg hatching.

A pulse of water came through regional river systems from contributing snow basins in late April, marking the commencement of the 2020 Fraser River freshet (Figure 3). Fraser River levels (Mission gauge; ID: 08MH024) continued to increase through May and initially peaked on June 5 (5.39 m) following a provincial warming trend in late-May. Cooler weather within contributing basins occurred in the early half of June, slowing the snowmelt, and resulting in a reduction in river levels (Figure 3).

A more consistent warming trend occurred in the latter half of June within basins contributing to the Fraser River freshet. Despite the majority of the snowpack within contributing basins at greatly reduced states and Lower Fraser River Water Level MIKE11 model[6] predicting a secondary, lower peak, the Lower Fraser River hit a higher peak on June 30 (Figure 3). The secondary peak of the season was over half a meter higher than the initial peak. Specifically, the Lower Fraser River peak for 2020 was 5.91 m. The considerable high-elevation snowpack in the Upper Fraser East basin and high local precipitation were two major contributors to the 2020 Lower Fraser River peak.

The Fraser River's peak height relative to recent seasons is a predictive variable that may help explain an associated year's larval abundance. If the current year's regional river levels far exceed that of preceding season, mosquito eggs laid between the high-water mark of both years could have remained dormant until current-year flood waters trigger their hatching. Because the peak of the Fraser River was far over 1.5 m higher in 2020 than in 2019, it is highly likely that the 2020 peak level triggered dormant eggs to hatch.

[6] http://bcrfc.env.gov.bc.ca/freshet/lower_fraser/LFR-10-DayFloodLevelForecasts.pdf

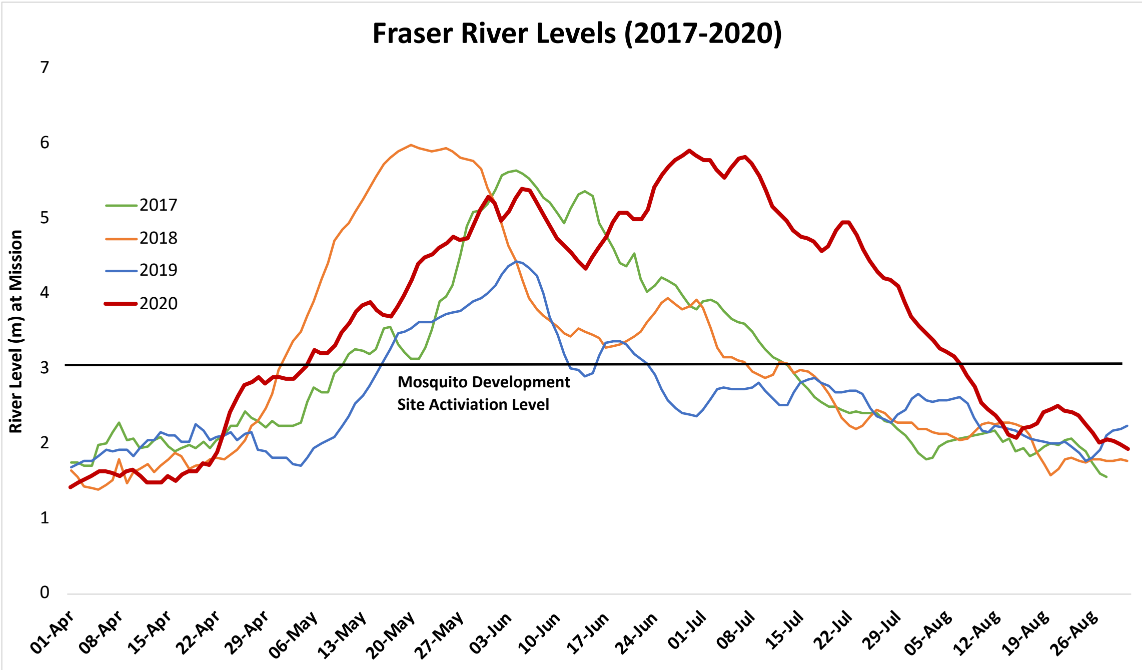


Figure 3. 2017-2020 river levels (m) as recorded at the Fraser River (Mission gauge, 08MH024), and as reported by the River Forecast Centre. Horizontal black line indicates level at which River-associated mosquito development sites become active.

Another predictive variable to describe the extent of mosquito larval abundance within a given year is the length of time the Fraser River at Mission is higher than 3 m. The horizontal black line in Figure 3 denotes the Fraser River height threshold (i.e. 3 m) at which mosquito development sites within the FVRD have been observed to become active. In 2020, the Fraser River reached that point on 6 May. The Fraser River remained above the 3 m threshold for 95 days in 2020. This total exceeds the total days above 3m observed in 2018 (i.e. 67 days), the most recent high-water year. Although the 2018 peak was higher than the 2020 peak, the difference was only 0.08 m. Additionally, the 2018 peak occurred in mid-May when hatching cues were less prominent (Figure 3). Thus, mosquito development sites were not only wet for the bulk of the mosquito season in 2020, but local ambient temperatures were also higher during peak periods, resulting in abundant hatching cues that likely exceeded those of 2018.

The Fraser River rose at a relatively slow, consistent rate in 2020 (Figure 3). When the River rises in this manner, floodwater mosquito eggs laid on substrates at various river levels have optimal environmental hatching cues. When river levels rise at high rates in the early portion of the season, the typically cool highly oxygenated water moving through the system makes it more challenging for mosquito eggs to hatch. However, because the initial and subsequent 2020 peaks occurred in June, ambient temperatures were ideal for mass mosquito egg hatching events and high larval development rates.

By mid-July 2020, all the snow basins contributing to the Fraser River were depleted of snow[7]. This depletion corresponds with a marked decline in the Fraser River levels by late July at the Mission gauge (Figure 3). When the Fraser River levels consistently remain

[7] http://bcrfc.env.gov.bc.ca/data/asp/realtime/

below 3 m, associated seepage sites reduce quickly. Thus, by early August many of the mosquito development sites were dry.

Larval Control

Monitoring within the FVRD began in late April. Appendix I A-C shows a map of larval densities found throughout the 2020 season. Larval abundance is assessed in the field using a system of ranges (0, 1-4, 5-49, 50+) for early and late instar mosquito larvae. In order to transfer these data to a frequency map (Appendix I), data are ultimately summarized and assigned to a hexbin representing an area of 21.65 ha. Only wet sites were included in the analysis. An intensity value representing the relative number and life stage of the larvae are assigned to each single sample. For each sample, late instar larvae ranges are weighted more heavily than early instar larvae ranges to indicate targeted life stage and treatment urgency. In this way, each sample is assigned an intensity value from 0 to 1. All sample intensity values are then averaged by hexbin. Thus, each hexbin is assigned an average intensity value from 0-1. The intensity value thresholds within Appendix I denoting ‘low’, ‘moderate’, ‘high’, and ‘very high’ were assigned based on biological significance and operational urgency.

Hexbins are used to aggregate point data, making general data trends visible at large scales. The primary drawback and disclaimer to hexbin analysis is that generalizations must be made. In general, hexbins denoted as ‘None Detected’ (i.e. white) or ‘Low’ (i.e. light sandy colour) indicate the average sample contained < 5 larval mosquitoes per dip. In most cases, hexbins with a moderate frequency (0.2875 - 0.525 intensity value; light orange colour) or greater indicate those which had an average of > 5 mosquito larvae per dip. Hexbins can contain one or greater sample point, may contain sample points that lie directly on hexbin borders, or contain treatment area associated with a point that is officially housed within a neighbourng hexbin; each of these circumstances may create skewed results.

In certain cases, hexbins denoted as ‘Non-Detected’ or ‘Low’ do have treatments associated with them (Appendix II A-C). In these cases, treatments may have been triggered by the larval activity of a representative site. Typically, sites that are located on Fraser River islands or those that are difficult to access may be associated with representative sites. Historically, when representative sites become active the other sites in the area have proven to also be active. Thus, sites with a previous designation of ‘Non-Detected’ or ‘Low’ may require a later treatment due to representative sites’ activity level without the need to sample. Of note, the areas with highest recorded larval abundance amongst known sites are Dewdney, Mission, Silverdale, Kent, and Seabird Island (Appendix I A-C).

Ground treatments started on May 5, indicating the close correlation between the 3 m Fraser River level and treatment requirements (Figure 4). Most ground treatments took place between early-May and mid-June with the rise of the Fraser River beyond 3 m (Figures 4, 5). However, ground treatments again increased with the second, higher peak in Fraser River levels.

Aerial treatments were also clustered around the two Fraser River peaks of the season (Figure 6). Technically, 13 aerial treatment days occurred within the FVRD in 2020, including two at Stave Lake on 28 May and 19 June. Two larger aerial campaigns were broken up in 2020 due to the large treatment areas and weather events restricting flight; the two campaign events were clustered around 10-12 June and 1-4 July (Figure 6). Aerial campaigns are generally considered region-wide treatments of the Fraser River Islands and valley. The total number of aerial treatment days (i.e., 13) in 2020 was six more than was conducted in 2018, the closest high-water year with comparable treatment area. The high total number of aerial treatment days in 2020 is a reflection of high water for an unprecedented number of days, coupled with frequent weather systems during aerial events that resulted in campaign delays. Appendix II A-C provide maps depicting where and how frequently treatments (i.e., ground and aerial, combined) took place in 2020.

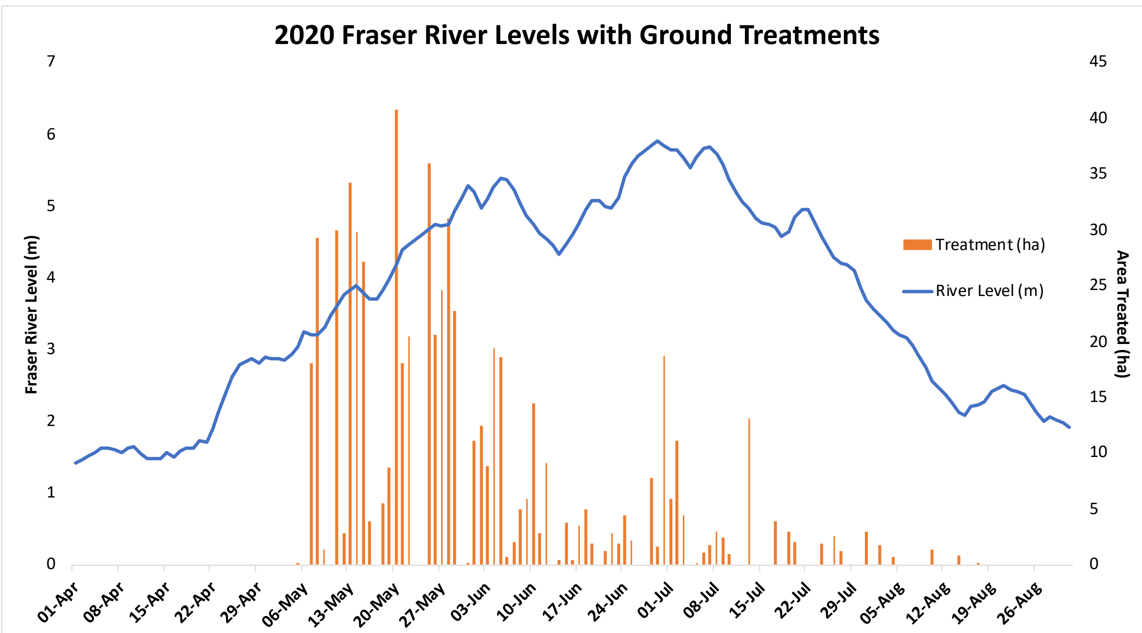


Figure 4. Fraser River levels (m; Mission gauge) and total mosquito development area treated by ground (ha) from April 1 – August 31, 2020.

Relative to the low-water year of 2019, floodwater mosquito development habitat was considerably increased in 2020 due to high snowpack in basins associated with the Fraser River and also to various local, large precipitation events. The Fraser River peaked during a period of high ambient temperatures which created ideal mosquito hatching environments. Additionally, the Fraser River at Mission remained above 3 m for 95 days, resulting in significantly increased need for mosquito larval treatments. River levels didn't start to recede below 3 m until mid- August. Ground treatments also tapered-off by mid-August. For perspective, ground treatments in most years are completed by mid-July. The final ground treatment took place on August 17 - the relative lateness of which is a reflection of all forementioned environmental factors occurring immediately prior to and during the 2020 mosquito season (Figure 4).

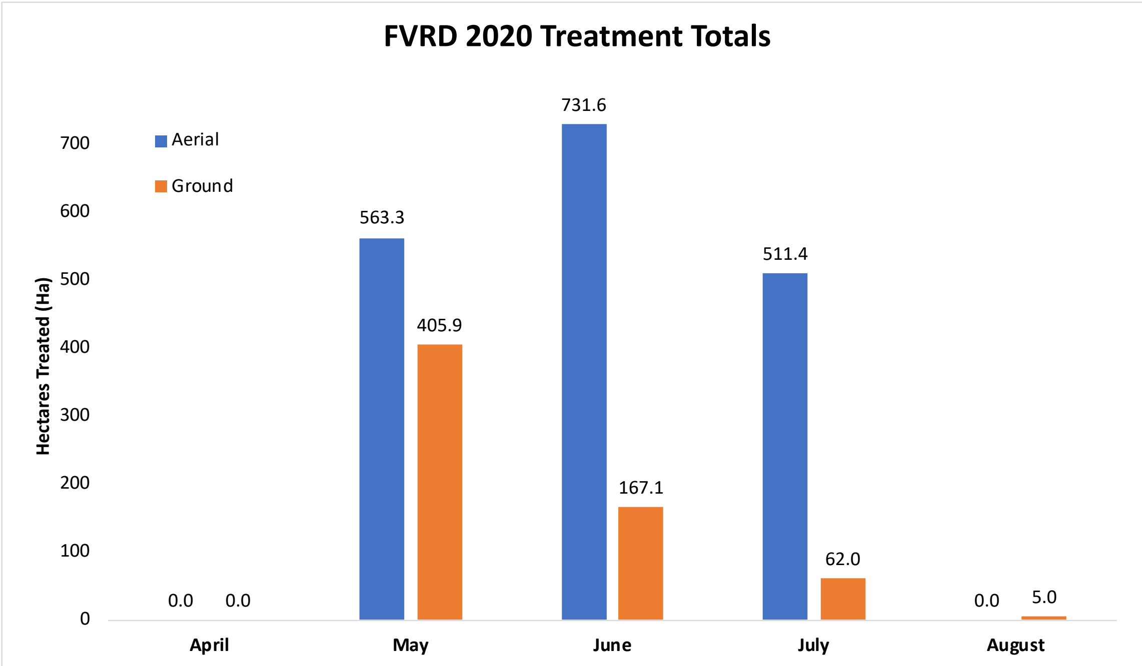


Figure 5. 2020 treated area (ha) by method (i.e. ground vs. aerial) and month from April – August.

Ground treatments were applied at a rate of 4 kg/ha. A total of 643 ha was treated by ground, equating to a total of approximately 2,572 kg of granular Aquabac® used (Figure 7). Typically, sites only require one treatment per season unless additional mosquito larvae are pushed into the site due to the movement of water. This season, certain sites needed to be treated multiple times due to prolonged mosquito development site existence. Additional treatments occurred at higher water levels than initial treatments, hence the treatment overlap is minimal.

Aerial treatments were conducted using both granular and liquid Aquabac®, with the same active ingredient. To compensate for increased canopy cover, aerial treatments were applied at a rate of approximately10 kg/ha using the granular product and 1,000 ml/ha using the liquid product. The liquid Aquabac® was used exclusively at Stave Lake. A total of 1,806 ha was treated by air, equating to a total of 17,363 kg of granular Aquabac® and 70,000 ml of liquid Aquabac® (Figures 6, 7). No known sites were missed in 2020 and no new sites were discovered. However, due to COVID-19 restrictions, MBL staff members were not able to accompany and guide pilots in 2020 and, thus, it is possible that sites were not treated as thoroughly as usual. The high number of concern calls associated with Fairfield Island indicate the possibility that sites on that island may have been over-looked. Appendix III shows more specific information about site, treatment timing, and extent of treatment for both ground and aerial treatments.

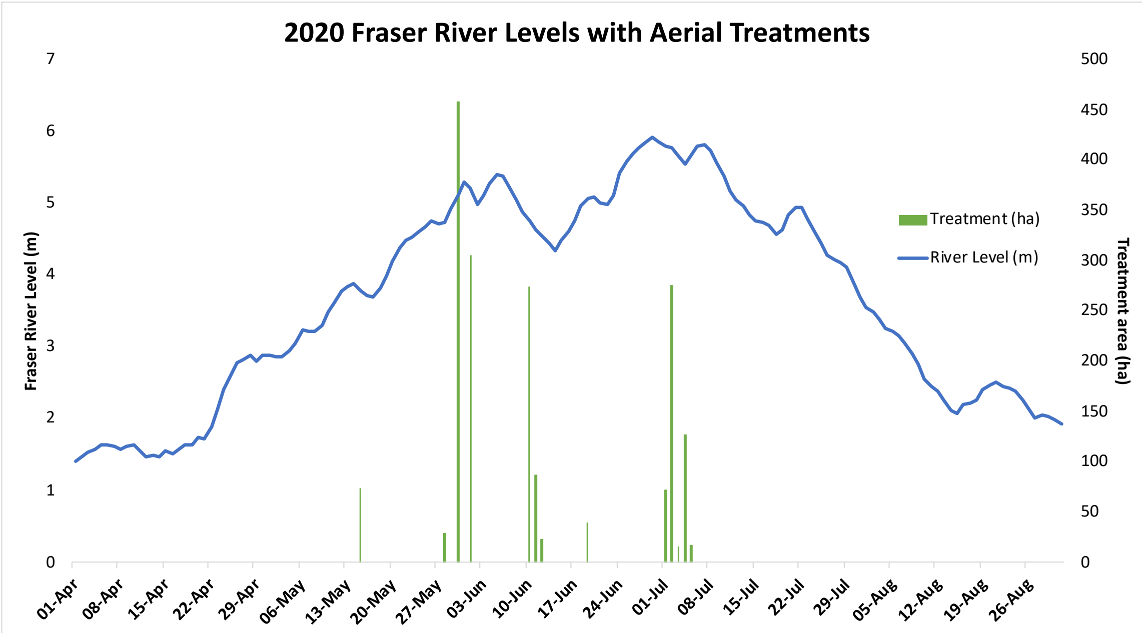
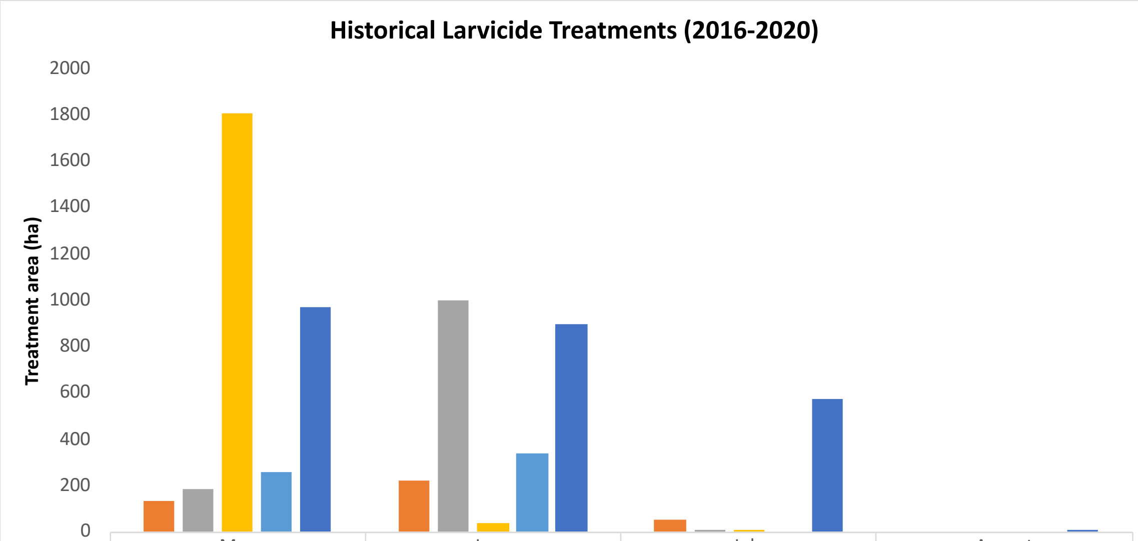


Figure 6. Aerial application events (green lines; ha) and Fraser River levels (blue line; m) as recorded at the Mission gauge from April 1 through August 31, 2020.

In comparing treatment areas since 2016, the total treated area exceeded all years, including the most recent high-water year of 2018 (Figure 7). Total treated area in 2020 surpassed total treated area in 2018 by 591 ha. In fact, the total treated area in 2020 was greater than the treated area in any year since prior to 2009. The record high treatment amount and area in 2020 is due to the higher-than-average snowpack in contributing basins, the prolonged snowmelt resulting in consistently high Fraser River levels, precipitation received locally during freshet peak(s), and the primary peak occurring during high ambient temperatures.



	May	June	July	August
2016	132	222	53	0
2017	184	1004	5	0
2018	1809	43	3	0
2019	259	339	0	0
2020	969	899	573	5

Figure 7. Historical Aquabac® treatments (ha) for May, June, July, and August (2016-2020). Treatments include ground and aerial applications.

Adult Mosquito Trapping

This year is the 9th consecutive year in which adult mosquito trapping stations have been established throughout the FVRD. The primary intention of the adult mosquito trapping program is to determine relative adult mosquito abundance, which serves as a quality assurance/quality control measure for larval mosquito control activities conducted by MBL technicians. Trap data allow MBL to compare intra and inter-annual nuisance levels.

Adult mosquito trap locations include the Hope Wastewater Plant, Abbotsford Wastewater Plant, Kent Wastewater Plant, Mission Raceway, and the Chilliwack Wastewater Plant. Monitoring inter-annual adult mosquito abundance at historical locations throughout this timeframe has enabled a comparison of abundance between years. Of note, adult mosquito counts include both male and female specimens.

A New Jersey Light trap was placed at each location and connected to a timer. These traps rely on mosquitoes' attraction to the heat and intensity of the light. A fan is attached to the trap, as well, which draws in mosquitoes that have been attracted to the light. The timer for the light was set to go on just before dusk and off just after dawn, capturing the time of the day when mosquitoes are most active. Instead of the standard light used in the light traps, a grow-light was used to increase trap counts.

Adult traps were set-up on May 14. Traps were checked approximately every 2 weeks between May 28 and August 24 (Table 3). At each set-up, trap functions were assessed and were all working properly prior to the sample night. Unfortunately, on four occasions, certain traps were found to have been unplugged at the collection event (Table 3). A total of 56 trap nights were conducted in 2020, which is approximately twice the average of trap nights calculated from 2011-2019.

Table 3. 2020 adult mosquito count by trap location and date. All N/A entries denote days in which traps were found to have been unplugged.

	Hope Wastewater Plant	Abbotsford Wastewater Plant	Kent Wastewater Plant	Mission Raceway	Chilliwack Wastewater Plant
28-May	2	2	7	N/A	5
08-Jun	2	9	5	N/A	2
18-Jun	14	8	13	0	4
24-Jun	15	1	11	5	7
02-Jul	3	5	1	19	9
09-Jul	N/A	3	1	25	2
17-Jul	5	2	5	30	4
24-Jul	5	2	7	N/A	7
30-Jul	3	3	6	15	5
07-Aug	7	0	2	20	0
13-Aug	4	0	0	30	0
24-Aug	2	0	0	20	1

Historically, adult mosquito trap abundance appears to have been directly related to the height of the lower Fraser River levels (Figure 8). However, using a simple correlation analysis with data since 2014, a correlation co-efficient (i.e. R) value of 0.294 is calculated. This is a considerably basic understanding of the relationship between adult mosquito production and Fraser River levels, acknowledging the relatively low power given the small sample size. The low correlation co-efficient suggests the two variables are not strongly related in their variation. The low R-value likely reveals that additional variables may account for greater portions of annual variation in adult mosquito abundance. A regression analysis may provide better understanding of the effects of multiple environmental conditions on the regional mosquito population. For example, more in-depth analyses might include the variables of precipitation, the number of days the Fraser River was higher than 3 m, potential for compounded number of mosquito eggs, and the management effort to name a few variables.

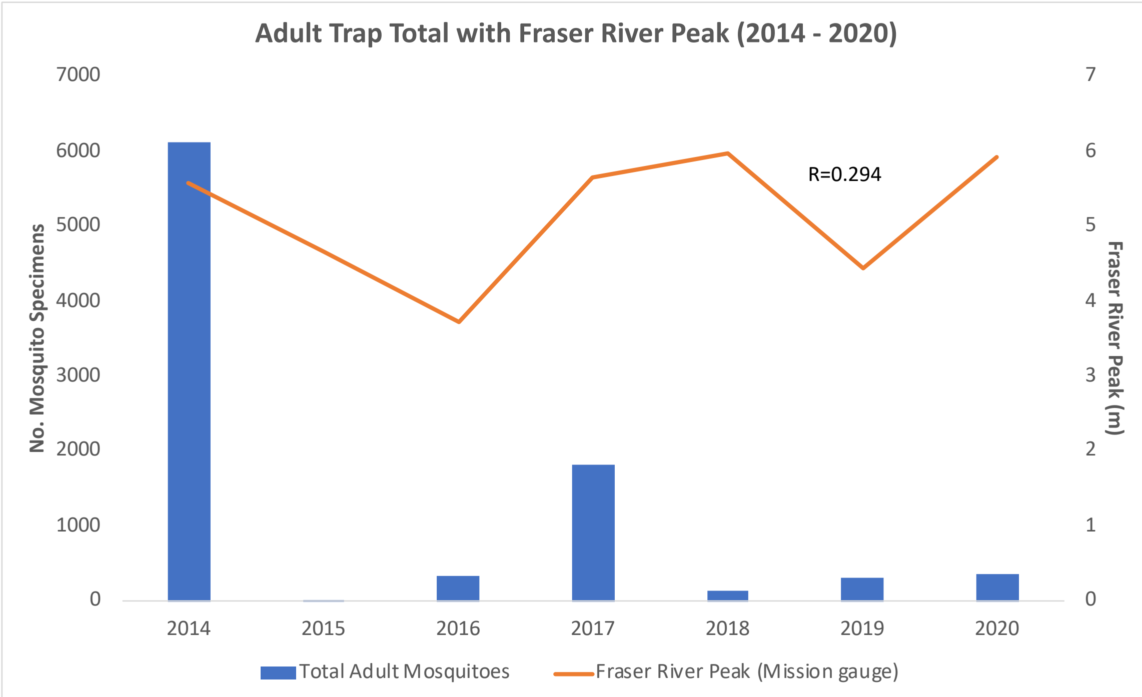


Figure 8. Total FVRD adult trap mosquito specimens with peak Fraser River level (Mission gauge) for 2014-2020. The correlation co-efficient (R) for the two variables is also indicated.

A total of 365 adult mosquito specimens were collected from FVRD traps in 2020 (Figure 8). This total is lower in comparison to 2014 and 2017, despite having a higher peak Fraser River level. In contrast, the 2020 trap total is higher than other years, including 2018, which had a slightly higher peak Fraser River level (Figure 8). It is likely that the extended high-water in 2020, in comparison to that of 2018, is partly responsible for the increased number of adult mosquitoes. Additionally, the total number of trap nights in 2018 was 35, as compared to 56 trap nights in 2020. Thus, comparisons between all years must take trap nights into consideration and interpret comparisons carefully.

The trend in 2020 adult trap abundance followed bi-modal curve, with the highest number of adult mosquitoes collected at the June 18/24 events (i.e. 39 mosquitoes) and at the July 17 event (i.e. 46 mosquitoes; Table 2). The high abundance of adult mosquitoes collected from those trap nights is likely due to dispersal from the initial Fraser River peak in early June and the primary peak at the end of June. Typically, adult mosquitoes begin to disperse at least 2-3 weeks after the peak in the regional Fraser River levels. Depending on wind direction and velocity, the dispersal may be accelerated or decelerated.

The highest number of adult mosquitoes was collected from the Mission Raceway trap, with the exception of the few nights that the trap had been unplugged (Table 2). Matsqui Island, which is immediately across a channel of the Fraser River, has considerable mosquito development habitat. Micro-mosquito development sites were likely created as a function of heavy debris movement on the Fraser River islands. These sites were transitory, and the displacement of the larval mosquitoes was difficult to locate and, thus, to treat. It is likely that mosquitoes that were able to emerge in 2020 dispersed directly to the Mission Raceway area.

Adult mosquito specimens from FVRD traps were discarded following counting. However, mosquito specimens from 11 trap locations (i.e., 56 trap nights, 486 specimens) were collected at regional sites outside of the FVRD. Site similarity and proximity to FVRD trap sites enable species composition extrapolation with relative confidence. Future efforts to ensure trap content preservation includes increased staff training, clearer chain-of-custody forms, and continued development of the real-time data collection application.

Adult mosquito specimen identification was conducted using a 60X microscope. Mosquito identification was conducted by a trained professional using keys developed from Wood et al (1979) and Darsie and Ward (2005). The species confirmed in the adult traps were *Aedes vexans, Ae. sticticus, Ae, cinereus, Ae. punctor, Ae. canadensis, Ae. japonicus, Culex tarsalis, Cx. Pipiens, Cx. Incidens,* and *Coquillettidia perturbans*. Certain indistinguishable specimens were either unknown or identified as either the *Aedes* or *Culex* genus.

Adult traps were established on May 7, 23, and 28, but no adult mosquitoes were caught. During the period in which adult mosquitoes were caught (i.e., June 5 – August 20), floodwater mosquito species were found in high abundance. The abundance and frequency of floodwater mosquitoes throughout the season is indicative of the length of time that floodwater mosquito habitat was active in 2020. The floodwater or floodwater-associated species that comprised the bulk of specimens were *Aedes vexans*, *Ae. sticticus*, and *Coquillettidia perturbans* (Figure 9).

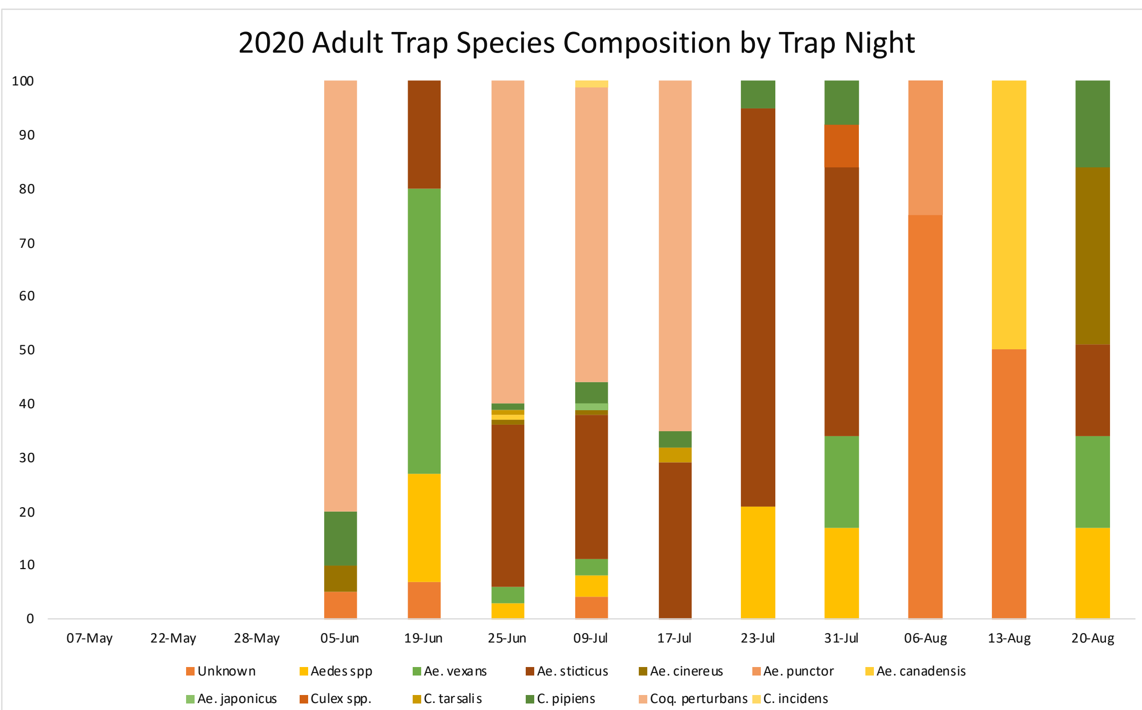


Figure 9. 2020 adult trap species composition by trap night from traps within the Lower Mainland outside of the FVRD.

An additional trend to note is the increase in container/temporary natural environment mosquito species (i.e., *Culex pipiens, Cx. tarsalis)* toward the end of the summer season (Figure 9). As ambient temperatures increase, container mosquito species or those that can be found in temporary natural environments increase. The confirmation of *Aedes japonicus* from July 9 trapping efforts in City of Coquitlam is also important to discuss due to its rare occurrence and a success as a vector for West Nile virus, St. Louis encephalitis, dengue, chikungunya, and Japanese encephalitis. The species was first reported in British Columbia in 2015 (Jackson et al. 2015). The specimen was confirmed by a secondary source and reported to Director of the Entomological Society of BC at the University of British Columbia. While *Ae. japonicus* has not been identified within the FVRD, there is comparable habitat to the area in which the specimen was collected.

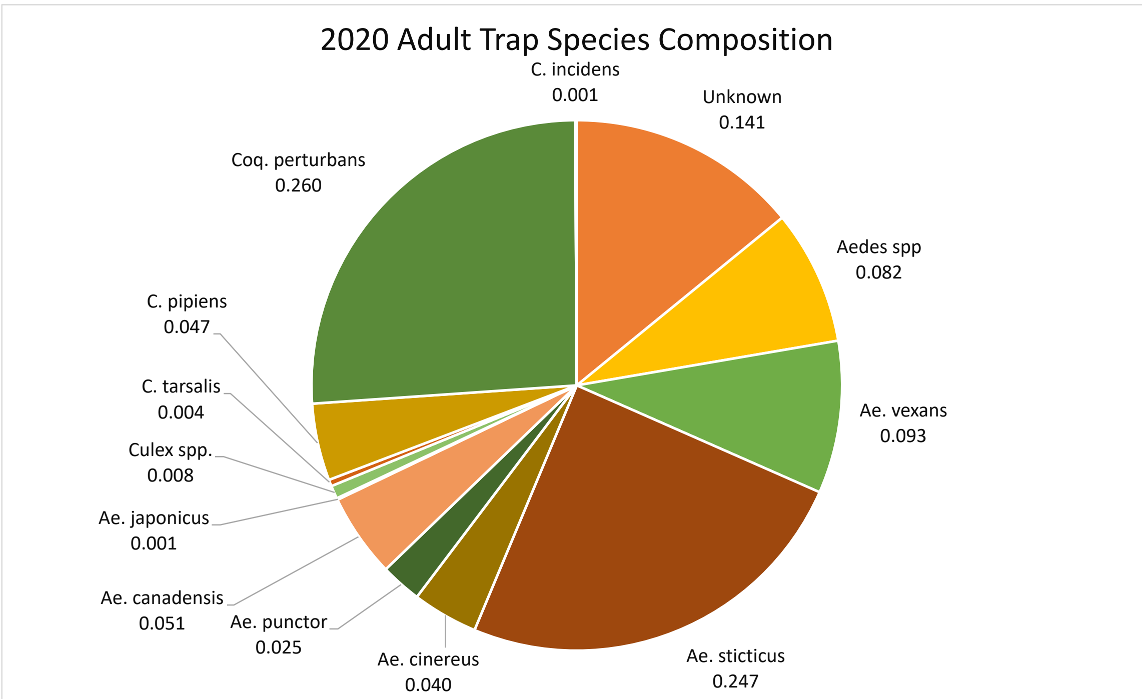


Figure 10. 2020 mosquito species composition from adult mosquito trap established throughout the Lower Mainland outside of FVRD.

Overall, *Aedes* species comprised the majority of the species in 2020 traps (i.e., 53.9%; Figure 10). As the dominant floodwater species, *Aedes* species were found throughout the mosquito season, indicating the long-term presence of floodwater habitat and continuous hatching cues. *Coquillettidia perturbans* comprised the next highest percentage of species (i.e., 26%). The primary habitat for *Cq. perturbans* is emergent vegetation, and more specifically *Typha* species (Batzer and Sjogren 2012). Consistently high Fraser River levels of 2020 may have created additional habitat for *Cq. perturbans.* The high presence of *Cq. perturbans* was also noted in similar abundance and from similar areas by Jackson and Patterson (2018) during the high-water year of 2018. Thus, higher-water years may yield greater habitat and hatching cues for *Cq. perturbans*. Known areas with high *Cq. perturbans* presence or suitable habitat should be prioritized in high-water years. There was a relatively smaller percentage of *Culex* specimens in 2020 (i.e., 6%) in comparison to trap results in 2019. Reasons for this discrepancy are unknown, however may be due to a reduction in potential habitat given the high, moving water.

Public Relations

Maintaining positive public relations remains a high priority for MBL. Public relations occur on several levels: in-person communication with members of the public, the mosquito hotline, presentations to staff and politicians, responding to e-mails, and continuing our social media presence. MBL continues to look for new areas to expand this aspect of our program and to improve our communication techniques.

Phone Calls and Emails

The total number of calls received in 2020 was 138. Of those, the total number of concern calls and emails received in 2020 was 130. Eight (8) calls were inquiry-based and primarily received in April, with residents requesting adult mosquito abundance predictions for the up-coming mosquito season or to ensure certain sites would again be treated in 2020. A total of five (5) emails were received. This high number of concern calls and emails is a reflection not only of a high Fraser River peak and the considerably long span the Fraser River levels were maintained, but also a reflection of a compound number of mosquito eggs from the 2019 season.

The majority of hotline calls and emails (i.e. 69 %) was received between 23 and 27 June (Figure 9). Adult mosquitoes begin to disperse from mosquito development sites approximately 2-3 weeks after the peak in the regional Fraser River levels. Thus, it was not surprising that the highest mosquito hotline call volume occurred within that timeframe following the initial peak of the Fraser River on June 5 (Figure 9).

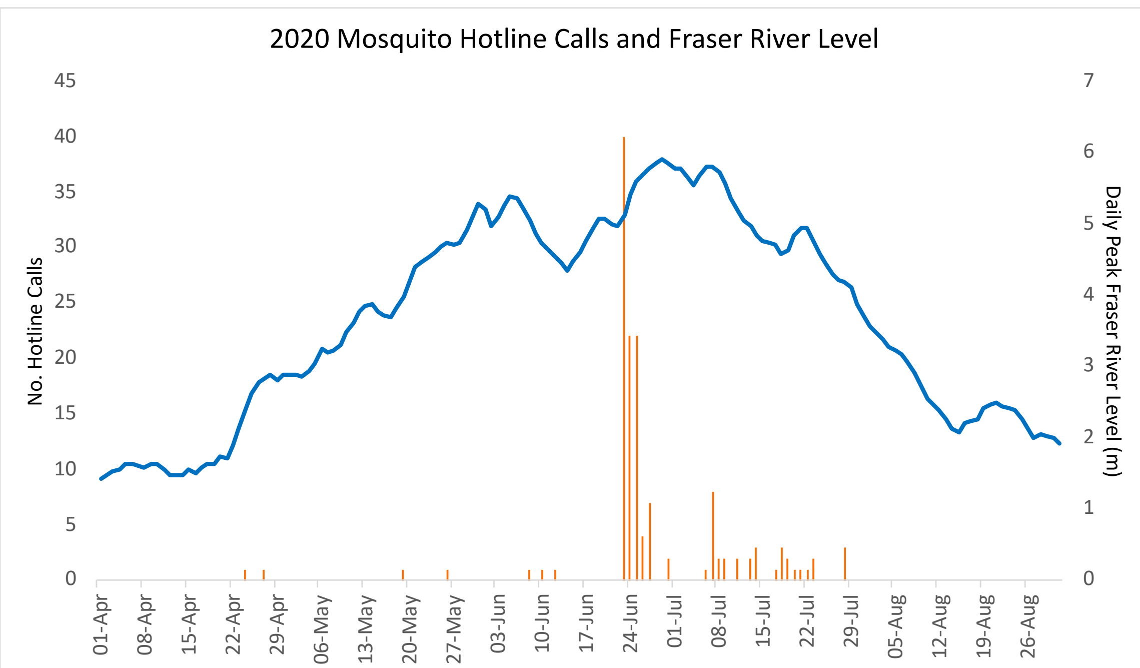


Figure 11. 2020 MBL mosquito hotline call volume by day with Fraser River daily peak (m; Mission gauge).

Appendix IV is a map of concern call distribution throughout the FVRD. The majority of calls was received in Chilliwack (i.e. 76 %). More specifically, most of those calls were from Fairfield Island. That area of Chilliwack is greatly affected by any mosquitoes that may have emerged from the considerable flood plain near Fairfield Island as well as nearby Carey Island and Comry Island. It is possible that certain mosquito development sites of Fairfield Island may have been over-looked during aerial treatments due to the inability of MBL staff members to accompany and guide helicopter pilots in 2020. If MBL staff members are unable to accompany helicopter pilots in the future, a pre-flight treatment GIS layer will be provided to pilots. Mission, Abbotsford, and Deroche were where the next highest percentage of calls came from (i.e. 5%, 4%, and 4%, respectively). The Appendix IV map indicates the close proximity of Mission and Abbotsford to Matsqui Island, and of Deroche to the prominent Nicomen Slough. Matsqui Island and Nicomen Slough have large mosquito development sites that, despite treating the greatest number of hectares since 2009, produced adult mosquitoes capable of dispersing to nearby communities.

The total number of concern calls in 2020 is considerably higher than the low number (i.e. 4) of concern calls recorded in 2019. This disparity is likely due to the significant difference in Fraser River peak levels, directly relating to the difference in active mosquito development area between the years. To illustrate the extent of flooding in 2020, Image 3 shows Cheam Campground largely under water on July 2.

Image 3. Cheam Campground on July 2, 2020.

All calls were returned within 24 hours of receipt if a phone number was provided. All emails were responded to within the same timeframe. Often, follow-up calls were also made to residents who had emailed if phone numbers were provided.

Direct Communications

Direct communication between MBL staff and the public can occur under many circumstances. The most common direct interfacing with the public occurs when technicians are in the field. While conducting site visits, MBL technicians are often asked questions by landowners or residents. These encounters provide an excellent opportunity for public relations. The fact that technicians are visibly monitoring and treating assures residents that attention is being given to mosquito abatement efforts. Additionally, an important outcome of these interactions can be the identification of new sites.

MBL contact information is disseminated when field technicians have direct communication with the public. Contact information for MBL includes the website address, an email, phone number, and social media sites (Twitter, Facebook). Additionally, MBL staff may provide residents with an outreach pamphlet (Image 4). The pamphlet includes information about the larval control product used, mosquito biology, and personal protective tips.

Image 4. MBL outreach pamphlet example

Education Outreach

For the 9th consecutive year, MBL has maintained a presence on social media. MBL has a Facebook account (facebook.com/MorrowMosquito), Twitter account (@MorrowMosquito), and Instagram account (linked to Facebook) which are regularly updated. Each platform includes posts regarding where monitoring events are taking place, what the environmental conditions are, and general larval abundance. As of 17 November 2020, the MBL Facebook page was up to 330 followers, which is an increase of 24 followers since this time in 2019. This season, the highest reach (i.e. 2,147) for a post most relevant to the FVRD mosquito control program occurred on May 19 (Image 5). The post was specific to monitoring and treatment activities occurring within the FVRD at mosquito development sites affected by the rising Fraser River.

Image 5. Facebook photo with description of MBL staff monitoring and treating Fraser River-associated mosquito development sites (May 19, 2020)

Given the provincial restrictions placed on large gatherings to reduce the spread of COVID-19, MBL enacted a company-wide policy to invest in virtually-available education outreach material instead of attending public events. As such, the MBL website (www.morrowbioscience.com) highlighted two sets of FAQs focused on (1) mosquito biology and disease transmission (Appendix V) and (2) the active ingredient used in control efforts (*Bacillus thuringiensis* var. *israelensis*) (Appendix VI). Additionally, a blog dedicated specifically to mosquitoes and COVID-19 was published on the MBL website (Appendix VII).

A media release was generated and approved by the FVRD program manager for distribution to a radio station in Abbotsford and a radio station in Chilliwack. Follow-up calls were made, but the story was not picked up. If radio-based education outreach is a focus of future efforts, contacts with local radio stations will be solidified farther in advance of any media release.

MBL staff members provided interviews to numerous sources during the 2020 mosquito season. Specifically, CTV (July 3), Global News (July 10), Mission City Record (July 14), and The Chilliwack Progress (July 15). All interviews described the reasons lending to high Fraser River levels in 2020 and provided water level predictions in line with provincial predictions. Additionally, MBL staff highlighted tips to reduce mosquito breeding habitat around private properties and suggested personal protective measures.

West Nile virus Summary

Although floodwater mosquito species in Canada are not primary West Nile virus (WNv) vectors, it is important to remain current in regional mosquito-related diseases. Along with its partners, the Government of Canada conducts on-going surveillance of WNv cases in humans between May 18 and August 29. Within that timeframe, there were no confirmed human case of WNv reported in BC[8]. Similarly, no horses or birds were confirmed to be positive for WNv within 2020, thus far. Of note, mosquito pool surveillance data is not reported to Health Canada from BC.

As Washington State and Idaho State share a border with British Columbia, it is important to follow WNv activity in those areas, as well. As of October 4, there were two human cases of WNv in Washington State; both were acquired in-state within counties in the

[8] https://www.canada.ca/en/public-health/services/diseases/west-nile-virus/surveillance-west-nile-virus/west-nile-virus-weekly-surveillance-monitoring.html

southern area of the state[9]. Additionally, 11 mosquito pools tested positive for WNv. No birds or horses/other mammals tested positive for WNv in 2020.

As of September 22, two human WNv cases were identified in Idaho[10]. Additionally, multiple mosquito pools tested positive for WNv. No bird specimens tested positive for the virus. All cases were identified within counties in the southern and southwestern portion of Idaho.

Zika virus Summary

No information regarding Canadian Zika cases has been reported by the Public Health Agency of Canada for 2020. However, HealthLinkBC reports that no Zika cases have originated in Canada due to presumed lack of vector mosquito species[11]. There have been human Zika cases reported in Canada prior to 2020, although those were determined to have been acquired while traveling.

According to Peach (2018), the primary Zika mosquito vectors (i.e. *Aedes aegypti*, *Ae. albopictus*) are not found in BC. *Ae. albopictus* has been found on east coast, but tested negative for Zika. There is currently a low risk for Zika virus to circulate within BC.

Program Reminders

A number of important issues must be addressed at the start of each season:

- Notify the Ministry of Environment of the FVRD intent to treat mosquitoes in 2021 under the FVRD Pest Management Plan. Notification should take place 2 months before the start of the season (the end of February at the latest).
- It is important to attach copies of all the mosquito development site maps with the Notice of Intent to Treat (NIT). NOTE: all sites have been re-mapped. This new data should be used to reprint maps for the purposes described above.

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[9] http://www.doh.wa.gov/DataandStatisticalReports/DiseasesandChronicConditions/WestNileVirus
[10] https://www.cdc.gov/westnile/statsmaps/preliminarymapsdata2020/disease-cases-state-2020.html
[11] https://www.healthlinkbc.ca/health-feature/zika-virus

References

Batzer, DP and Sjogren RD. 2012. Larval Habitat Characteristics of *Coquillettidia perturbans* (Diptera: Culicidae) in Minnesota. *The Canadian Entomologist* 118(**11**): 1193-1198.

Boisvert M and Boisvert J. 2000. Effects of *Bacillus thuringiensis* var. *israelensis* on Target and Non-Target Organisms: A review of laboratory and field experiments. *Biocontrol Sci Tech* 10:517-561.

Breeland SG and Pickard E (1967) Field Observations on Twenty-eight Broods of Floodwater Mosquitoes Resulting from Controlled Flooding of a Natural Habitat in the Tennessee Valley. *Mosq News* 27: 343-358.

Ciota, AT, AC Matacchiero, AM Kilpatrick, LD Kramer. 2014. The Effect of Temperature on Life History Traits of *Culex* Mosquitoes. *J Med Entomol*. 51(**1**): 55-62.

Jackson, M., P. Belton, S. McMahon, M. Hart, S. McCann, D. Azevedo, L. Hurteau. 2015. The First Record of aedes (Hulecoeteomyia) japonicus (Diptera: Culicidae) and Its Establishment in Western Canada. *J Med Entomol*. 53 (**1**): 241-244.

Jackson, M and Patterson, K. (2018). Metro Vancouver Final Report – Nuisance Mosquito Control Program 2018. December 2018. 74 pp.

Mohammad, A. and Chadee, DD. 2011. Effects of Different Temperature Regimes on the Development of *Aedes aegypti* (L.) (Diptera: Culicidae) Mosquitoes. *Acta Tropica* 119: 38-43.

Peach, D. (2018). An Updated List of the Mosquitoes of British Columbia with Distribution Notes. J. *Entomol. Soc. Brit. Columbia* 115: 126-129.

Trpis, M. and Horsfall, WR. (1969). Development of *Aedes sticticus* (Meigen)) in Relation to Temperature, Diet, Density, Depth. Annals Zoologici Fennici, 6(2): 156-160.

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Mosquito Larval Densities at Sample Locations (1/3)

Appendix I-A

2020

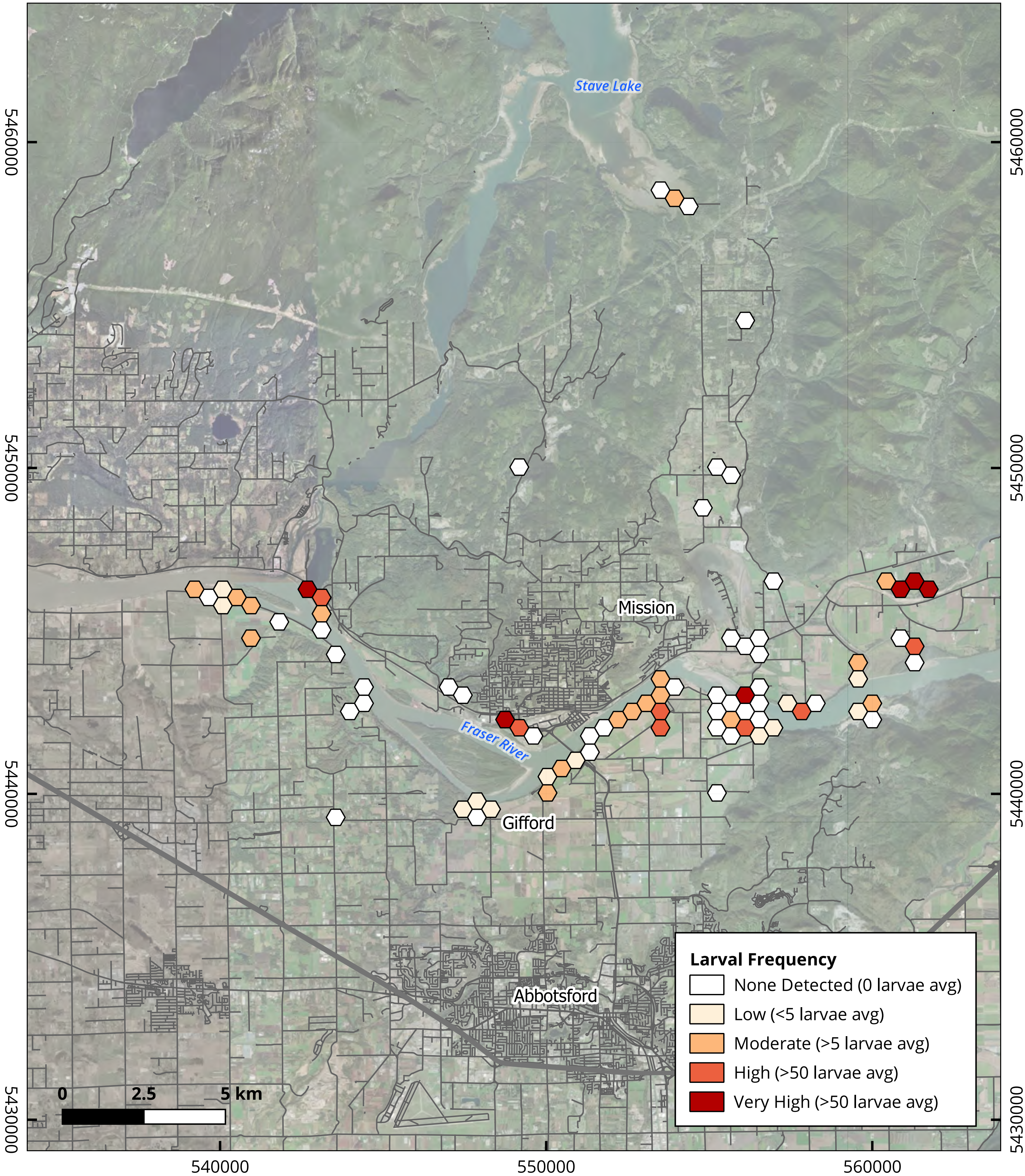
N

Morrow BioScience Ltd

PO Box 1013 Rossland, BC V0G 1Y0

gis@morrowbioscience.com 1(877)986-3363

Scale = 1 : 150,000 CRS = NAD83 UTM Zone 10N



Mosquito Larval Densities at Sample Locations (2/3)

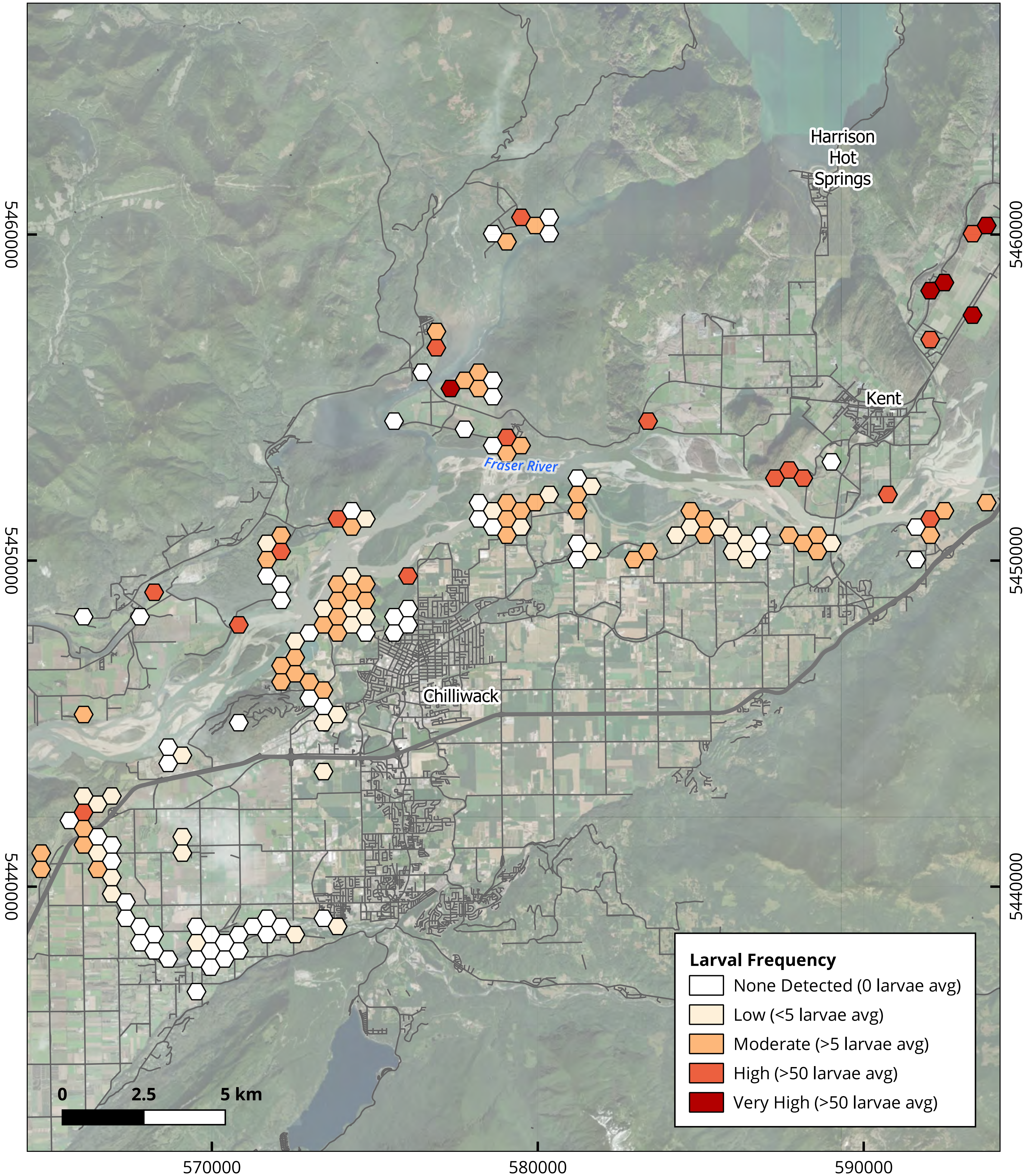
Appendix I-B

2020

Morrow BioScience Ltd
PO Box 1013 Rossland, BC V0G 1Y0
gis@morrowbioscience.com 1(877)986-3363

N

Scale = 1 : 150,000 CRS = NAD83 UTM Zone 10N



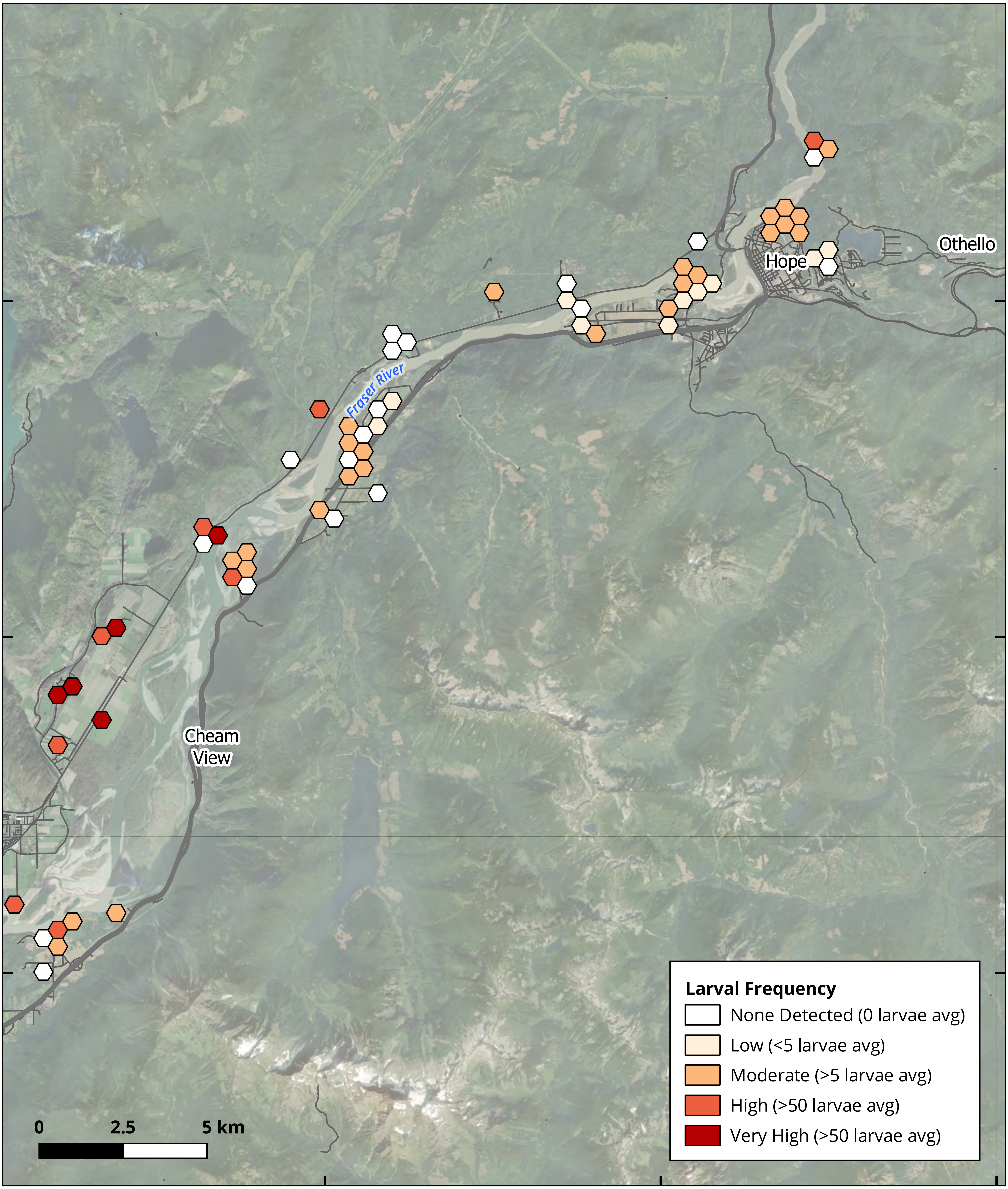
Mosquito Larval Densities at Sample Locations (3/3)

Appendix I-C

2020

Morrow BioScience Ltd
PO Box 1013 Rossland, BC V0G 1Y0
gis@morrowbioscience.com 1(877)986-3363

Scale = 1 : 150,000 CRS = NAD83 UTM Zone 10N



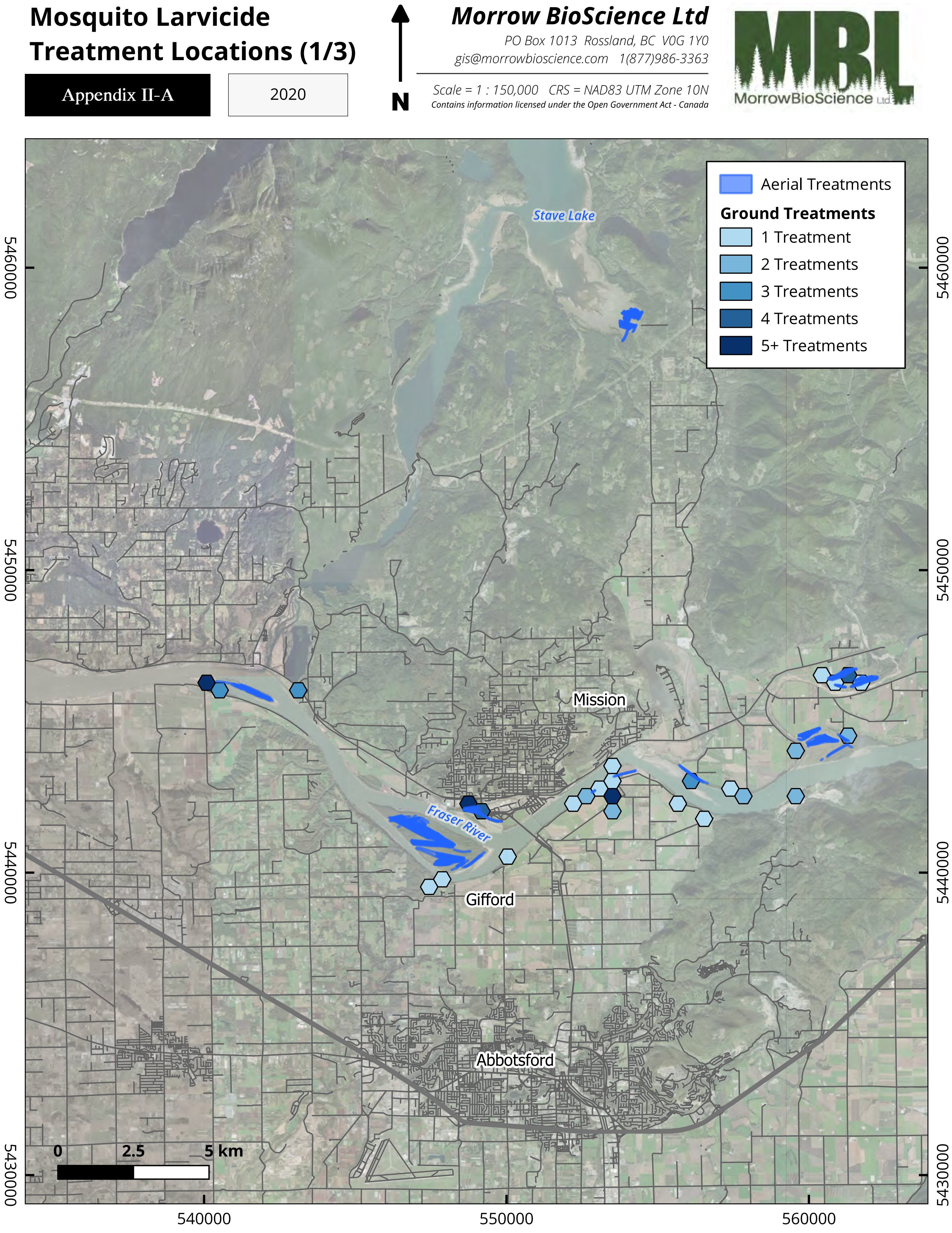
Mosquito Larvicide Treatment Locations (1/3)

Appendix II-A

2020

Morrow BioScience Ltd
PO Box 1013 Rossland, BC V0G 1Y0
gis@morrowbioscience.com 1(877)986-3363

Scale = 1 : 150,000 CRS = NAD83 UTM Zone 10N



Mosquito Larvicide Treatment Locations (2/3)

Appendix II-B

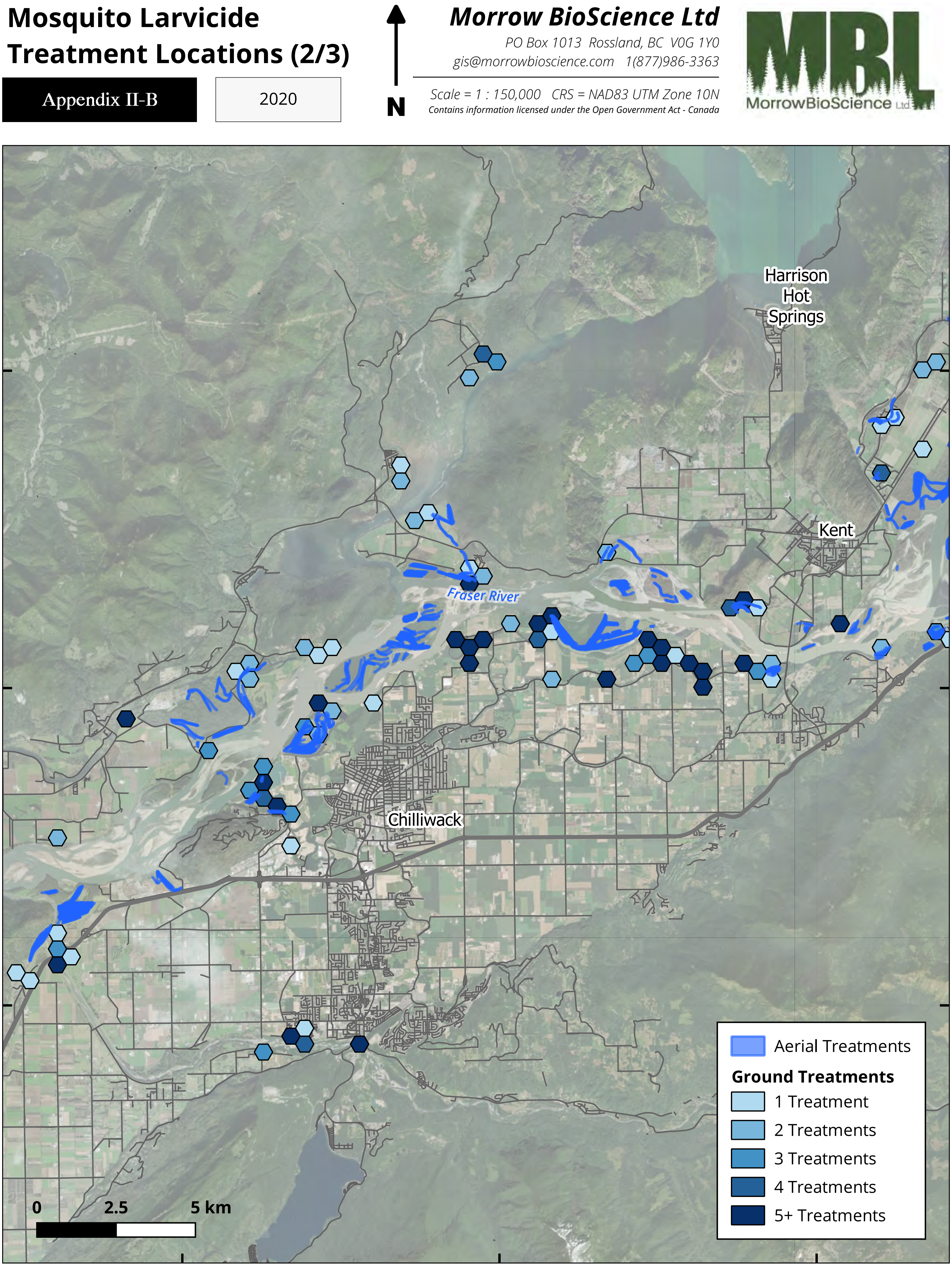
2020

Morrow BioScience Ltd

PO Box 1013 Rossland, BC V0G 1Y0

gis@morrowbioscience.com 1(877)986-3363

Scale = 1 : 150,000 CRS = NAD83 UTM Zone 10N



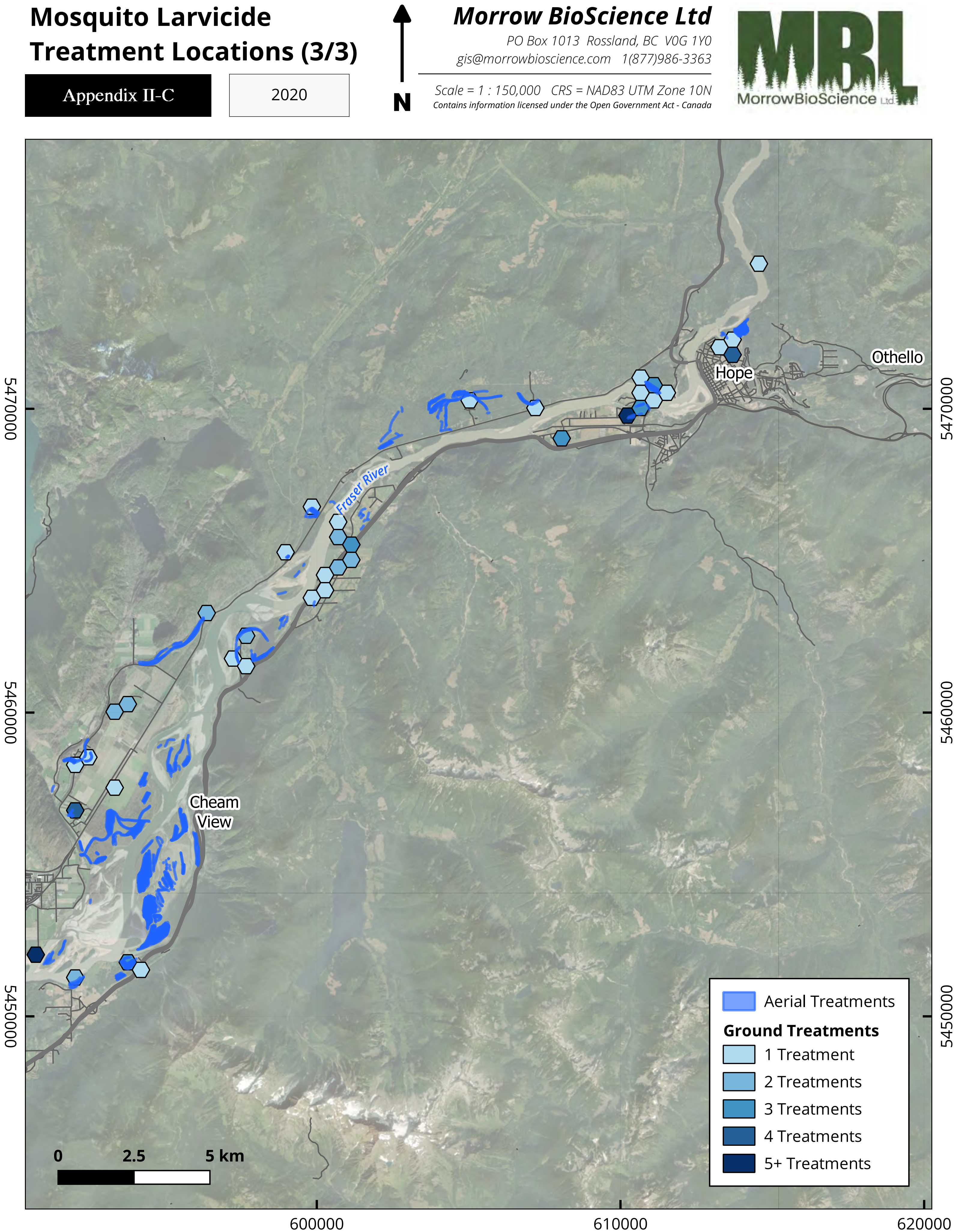
Mosquito Larvicide Treatment Locations (3/3)

Appendix II-C

2020

Morrow BioScience Ltd
PO Box 1013 Rossland, BC V0G 1Y0
gis@morrowbioscience.com 1(877)986-3363

Scale = 1 : 150,000 CRS = NAD83 UTM Zone 10N



Appendix III. 2020 treatment data (kg, ha) by site and date for all ground (A) and aerial (B) treatments

III-A: Ground Treatments

Site Code	Site Name	Treatment Date	Treatment Amount (Kg)	Treated Area (Ha)
FVRD-214	Matsqui FN	2020-05-05	0.50	0.13
FVRD-173	Yellow house	2020-05-07	14.50	3.63
FVRD-063	Island 22	2020-05-07	5.00	1.25
FVRD-142	Peters road	2020-05-07	45.00	11.25
FVRD-180	Landstrom Road	2020-05-07	6.00	1.50
FVRD-176	Bristol island	2020-05-07	2.00	0.50
FVRD-040	Thompson road	2020-05-08	3.00	0.75
FVRD-040	Thompson road	2020-05-08	5.00	1.25
FVRD-138	Deeper channel right side of road pathway	2020-05-08	32.00	8.00
FVRD-034	Sumas Sand and Gravel	2020-05-08	1.00	0.25
FVRD-077	Ballam Pond	2020-05-08	33.00	8.25
FVRD-075	Wentworth's Field	2020-05-08	17.00	4.25
FVRD-089	Ballam Ditch	2020-05-08	2.00	0.50
FVRD-100	Carey Road Field	2020-05-08	3.00	0.75
FVRD-089	Ballam Ditch	2020-05-08	2.00	0.50
FVRD-197	Royal Wood Golf Course	2020-05-08	3.00	0.75
FVRD-061	C4	2020-05-08	4.50	1.13
FVRD-042	Barrowtown	2020-05-08	1.00	0.25
FVRD-056	Dyke Road. Private house	2020-05-08	1.00	0.25
FVRD-056	Dyke Road. Private house	2020-05-08	2.00	0.50
FVRD-058	Skway First Nations South	2020-05-08	8.00	2.00
FVRD-148	St Elmo's road	2020-05-09	1.50	0.38
FVRD-151	Old Muslim College	2020-05-09	4.00	1.00
FVRD-206	Allendales Farm Channels	2020-05-11	42.00	10.50
FVRD-136	Seabird Road Island at Powerlines	2020-05-11	18.00	4.50
FVRD-090	Kilby Field North	2020-05-11	8.50	2.13
FVRD-090	Kilby Field North	2020-05-11	0.50	0.13
FVRD-106	Lougheed Highway pump station	2020-05-11	8.50	2.13
FVRD-115	Vasha's House	2020-05-11	8.00	2.00
FVRD-115	Vasha's House	2020-05-11	6.00	1.50
FVRD-002	Glen Valley Poplar Bar - West	2020-05-11	0.50	0.13
FVRD-141	Powerlines	2020-05-11	28.00	7.00
FVRD-227	Skway bulldozer path	2020-05-12	0.10	0.03
FVRD-085	Driveway on the opposite side of Thiyothel sign	2020-05-12	1.00	0.25
FVRD-076	Ballam Dyke	2020-05-12	7.00	1.75
FVRD-068	Sandpiper	2020-05-12	3.00	0.75
FVRD-044	C1	2020-05-12	0.50	0.13
FVRD-148	St Elmo's road	2020-05-13	3.00	0.75
FVRD-120	Ferry Road 2	2020-05-13	4.50	1.13
FVRD-138	Deeper channel right side of road pathway	2020-05-13	6.00	1.50
FVRD-135	Blue ridge Ranch	2020-05-13	10.50	2.63
	Ferry island channel	2020-05-13	6.00	1.50
FVRD-142	Peters road	2020-05-13	16.50	4.13
FVRD-173	Yellow house	2020-05-13	6.00	1.50
FVRD-109	End of Edmonson Road	2020-05-13	6.00	1.50
FVRD-008	Stave river wetland	2020-05-13	62.00	15.50
FVRD-142	Peters road	2020-05-13	16.50	4.13
FVRD-048	Nikomen island	2020-05-14	6.00	1.50
FVRD-015	Mission raceway	2020-05-14	7.00	1.75

Site Code	Site Name	Treatment Date	Treatment Amount (Kg)	Treated Area (Ha)
FVRD-015	Mission raceway	2020-05-14	5.00	1.25
FVRD-116	Ferry Road	2020-05-14	6.00	1.50
FVRD-063	Island 22	2020-05-14	21.00	5.25
FVRD-113	Wilbourne Road	2020-05-14	1.00	0.25
FVRD-015	Mission raceway	2020-05-14	2.00	0.50
FVRD-015	Mission raceway	2020-05-14	5.00	1.25
FVRD-015	Mission raceway	2020-05-14	12.00	3.00
FVRD-015	Mission raceway	2020-05-14	3.00	0.75
FVRD-015	Mission raceway	2020-05-14	6.00	1.50
FVRD-038	Norrish Creek	2020-05-14	8.00	2.00
FVRD-038	Norrish Creek	2020-05-14	6.00	1.50
FVRD-038	Norrish Creek	2020-05-14	6.00	1.50
FVRD-038	Norrish Creek	2020-05-14	6.00	1.50
FVRD-038	Norrish Creek	2020-05-14	0.50	0.13
FVRD-038	Norrish Creek	2020-05-14	6.00	1.50
FVRD-038	Norrish Creek	2020-05-14	6.00	1.50
FVRD-180	Landstrom Road	2020-05-14	7.00	1.75
FVRD-211	Olund Trail	2020-05-15	0.50	0.13
FVRD-218	Dyke	2020-05-15	1.00	0.25
FVRD-119	Tuyttens Road pond	2020-05-15	5.00	1.25
FVRD-004	Glen Valley Poplar Bar - East	2020-05-15	1.00	0.25
FVRD-077	Ballam Pond	2020-05-15	32.00	8.00
FVRD-089	Ballam Ditch	2020-05-15	44.00	11.00
FVRD-098	Kitchen Hall Road	2020-05-15	1.00	0.25
FVRD-176	Bristol island	2020-05-15	5.00	1.25
FVRD-194	Hope golf course active channels	2020-05-15	19.00	4.75
FVRD-030	Matsqui Trail Park	2020-05-16	5.00	1.25
FVRD-042	Barrowtown	2020-05-16	6.00	1.50
FVRD-044	C1	2020-05-16	1.00	0.25
FVRD-058	Skway First Nations South	2020-05-16	4.00	1.00
FVRD-062	Progress Way	2020-05-18	3.00	0.75
FVRD-061	C4	2020-05-18	3.00	0.75
FVRD-061	C4	2020-05-18	3.00	0.75
FVRD-061	C4	2020-05-18	6.00	1.50
FVRD-058	Skway First Nations South	2020-05-18	6.00	1.50
FVRD-034	Sumas Sand and Gravel	2020-05-18	1.00	0.25
FVRD-176	Bristol island	2020-05-18	0.20	0.05
FVRD-035	Dewdney regional park	2020-05-19	4.00	1.00
FVRD-053	Queens island- athey no1- dyke Road	2020-05-19	5.00	1.25
FVRD-099	End of Carey Road	2020-05-19	4.00	1.00
FVRD-100	Carey Road Field	2020-05-19	3.00	0.75
FVRD-206	Allendales Farm Channels	2020-05-19	19.00	4.75
FVRD-144	Klopp farm	2020-05-20	1.50	0.38
FVRD-145	Ditch across from farmer field	2020-05-20	4.50	1.13
FVRD-138	Deeper channel right side of road pathway	2020-05-20	11.50	2.88
FVRD-260	Seabird ditch	2020-05-20	11.00	2.75
FVRD-008	Stave river wetland	2020-05-20	24.00	6.00
FVRD-136	Seabird Road Island at Powerlines	2020-05-20	7.00	1.75
FVRD-173	Yellow house	2020-05-20	12.00	3.00

Site Code	Site Name	Treatment Date	Treatment Amount (Kg)	Treated Area (Ha)
FVRD-194	Hope golf course active channels	2020-05-20	6.00	1.50
FVRD-180	Landstrom Road	2020-05-20	6.00	1.50
FVRD-180	Landstrom Road	2020-05-20	6.00	1.50
FVRD-135	Blue ridge Ranch	2020-05-20	2.50	0.63
FVRD-121	Ferry Island	2020-05-20	5.00	1.25
	Ferry island channel	2020-05-20	6.00	1.50
FVRD-109	End of Edmonson Road	2020-05-20	12.00	3.00
FVRD-109	End of Edmonson Road	2020-05-20	1.00	0.25
FVRD-107	Camp River slough	2020-05-20	1.00	0.25
FVRD-104	Camp River Road House	2020-05-20	6.00	1.50
FVRD-101	Jesperson Road	2020-05-20	1.00	0.25
FVRD-076	Ballam Dyke	2020-05-20	12.00	3.00
FVRD-106	Lougheed Highway pump station	2020-05-20	5.00	1.25
FVRD-075	Wentworth's Field	2020-05-20	1.00	0.25
FVRD-075	Wentworth's Field	2020-05-20	21.00	5.25
FVRD-233	Vedder River Campground	2020-05-21	1.00	0.25
FVRD-048	Nikomen island	2020-05-21	6.00	1.50
FVRD-048	Nikomen island	2020-05-21	4.00	1.00
FVRD-048	Nikomen island	2020-05-21	5.00	1.25
FVRD-143	Lougheed house	2020-05-21	1.50	0.38
FVRD-252	Ruby Field	2020-05-21	30.00	7.50
FVRD-111	Gill Road	2020-05-21	1.00	0.25
FVRD-068	Sandpiper	2020-05-21	2.00	0.50
FVRD-015	Mission raceway	2020-05-21	5.00	1.25
FVRD-015	Mission raceway	2020-05-21	6.00	1.50
FVRD-141	Powerlines	2020-05-21	4.50	1.13
FVRD-161	Chawathil active ditch west site	2020-05-21	0.30	0.08
FVRD-195	Chawathil Channel	2020-05-21	3.00	0.75
FVRD-190	Rotary by chinook	2020-05-21	1.00	0.25
FVRD-113	Wilbourne Road	2020-05-21	1.00	0.25
FVRD-110	Camp Slough	2020-05-21	1.00	0.25
FVRD-115	Vasha's House	2020-05-22	6.00	1.50
FVRD-115	Vasha's House	2020-05-22	6.00	1.50
FVRD-090	Kilby Field North	2020-05-22	6.00	1.50
FVRD-064	Antons house	2020-05-22	6.00	1.50
FVRD-064	Antons house	2020-05-22	4.00	1.00
FVRD-056	Dyke Road. Private house	2020-05-22	12.00	3.00
FVRD-116	Ferry Road	2020-05-22	8.00	2.00
FVRD-063	Island 22	2020-05-22	32.00	8.00
FVRD-063	Island 22	2020-05-22	2.00	0.50
FVRD-030	Matsqui Trail Park	2020-05-25	6.00	1.50
FVRD-008	Stave river wetland	2020-05-25	29.00	7.25
FVRD-061	C4	2020-05-25	14.00	3.50
FVRD-061	C4	2020-05-25	18.00	4.50
FVRD-044	C1	2020-05-25	12.00	3.00
FVRD-197	Royal Wood Golf Course	2020-05-25	22.00	5.50
FVRD-098	Kitchen Hall Road	2020-05-25	5.00	1.25
FVRD-089	Ballam Ditch	2020-05-25	38.00	9.50
FVRD-222	Skway FN channel	2020-05-26	6.00	1.50
FVRD-058	Skway First Nations South	2020-05-26	15.00	3.75

Site Code	Site Name	Treatment Date	Treatment Amount (Kg)	Treated Area (Ha)
FVRD-061	C4	2020-05-26	22.50	5.63
FVRD-053	Queens island- athey no1- dyke Road	2020-05-26	12.00	3.00
FVRD-053	Queens island- athey no1- dyke Road	2020-05-26	6.00	1.50
FVRD-035	Dewdney regional park	2020-05-26	6.00	1.50
FVRD-206	Allendales Farm Channels	2020-05-26	14.00	3.50
FVRD-095	Jess Road	2020-05-26	1.00	0.25
FVRD-090	Kilby Field North	2020-05-27	6.00	1.50
FVRD-090	Kilby Field North	2020-05-27	19.00	4.75
FVRD-090	Kilby Field North	2020-05-27	2.00	0.50
FVRD-115	Vasha's House	2020-05-27	6.00	1.50
FVRD-115	Vasha's House	2020-05-27	12.00	3.00
FVRD-115	Vasha's House	2020-05-27	18.00	4.50
FVRD-115	Vasha's House	2020-05-27	9.00	2.25
FVRD-115	Vasha's House	2020-05-27	6.00	1.50
FVRD-115	Vasha's House	2020-05-27	8.00	2.00
FVRD-107	Camp River slough	2020-05-27	2.00	0.50
FVRD-104	Camp River Road House	2020-05-27	1.50	0.38
FVRD-099	End of Carey Road	2020-05-27	3.00	0.75
FVRD-100	Carey Road Field	2020-05-27	4.50	1.13
FVRD-076	Ballam Dyke	2020-05-27	0.50	0.13
FVRD-091	McSween Ditch	2020-05-27	1.00	0.25
FVRD-085		2020-05-28	6.00	1.50
FVRD-191		2020-05-28	3.00	0.75
FVRD-191		2020-05-28	3.00	0.75
FVRD-191		2020-05-28	5.00	1.25
FVRD-191		2020-05-28	6.00	1.50
FVRD-191		2020-05-28	5.00	1.25
FVRD-191		2020-05-28	3.00	0.75
FVRD-148	St Elmo's road	2020-05-28	6.00	1.50
FVRD-147	Deeper in George road channel right side	2020-05-28	6.00	1.50
FVRD-147	Deeper in George road channel right side	2020-05-28	5.00	1.25
FVRD-145	Ditch across from farmer field	2020-05-28	7.00	1.75
FVRD-144	Klopp farm	2020-05-28	4.50	1.13
FVRD-138	Deeper channel right side of road pathway	2020-05-28	6.00	1.50
FVRD-111	Gill Road	2020-05-28	2.00	0.50
FVRD-142	Peters road	2020-05-28	4.50	1.13
FVRD-121	Ferry Island	2020-05-28	37.50	9.38
FVRD-113	Wilbourne Road	2020-05-28	4.50	1.13
FVRD-110	Camp Slough	2020-05-28	2.00	0.50
FVRD-109	End of Edmonson Road	2020-05-28	8.00	2.00
	Cheam Campground	2020-05-29	1.00	0.25
	Cheam Campground	2020-05-29	6.00	1.50
FVRD-186	Fraser River at Trafalgar Flat 13	2020-05-29	6.00	1.50
FVRD-194	Hope golf course active channels	2020-05-29	6.00	1.50
FVRD-194	Hope golf course active channels	2020-05-29	22.50	5.63
FVRD-180	Landstrom Road	2020-05-29	18.00	4.50
FVRD-173	Yellow house	2020-05-29	8.50	2.13
FVRD-116	Ferry Road	2020-05-29	4.50	1.13
FVRD-063	Island 22	2020-05-29	18.50	4.63
FVRD-227		2020-05-31	0.50	0.13

Site Code	Site Name	Treatment Date	Treatment Amount (Kg)	Treated Area (Ha)
FVRD-233	Vedder River Campground	2020-06-01	0.50	0.13
FVRD-064		2020-06-01	12.00	3.00
FVRD-056		2020-06-01	6.00	1.50
FVRD-098	Kitchen Hall Road	2020-06-01	3.00	0.75
FVRD-094	End of Ballam	2020-06-01	0.50	0.13
FVRD-089	Ballam Ditch	2020-06-01	18.00	4.50
FVRD-077	Ballam Pond	2020-06-01	4.50	1.13
FVRD-190	Rotary by chinook	2020-06-02	1.50	0.38
FVRD-147	Deeper in George road channel right side	2020-06-02	4.00	1.00
FVRD-222	Skway FN channel	2020-06-02	4.00	1.00
FVRD-058	Skway First Nations South	2020-06-02	6.00	1.50
FVRD-206	Allendales Farm Channels	2020-06-02	10.50	2.63
FVRD-225		2020-06-02	24.00	6.00
FVRD-090	Kilby Field North	2020-06-03	6.00	1.50
FVRD-232	Paul's house	2020-06-03	3.00	0.75
FVRD-104	Camp River Road House	2020-06-03	5.50	1.38
FVRD-099	End of Carey Road	2020-06-03	1.50	0.38
FVRD-091	McSween Ditch	2020-06-03	4.50	1.13
FVRD-091	McSween Ditch	2020-06-03	15.00	3.75
FVRD-048	Nikomen island	2020-06-04	6.00	1.50
FVRD-231	Cheam Campground tree hole	2020-06-04	7.50	1.88
	Cheam Campground	2020-06-04	6.00	1.50
FVRD-120	Ferry Road 2	2020-06-04	6.00	1.50
FVRD-151	Old Muslim College	2020-06-04	30.00	7.50
FVRD-145	Ditch across from farmer field	2020-06-04	0.75	0.19
FVRD-172	Wild rose	2020-06-04	0.40	0.10
FVRD-173	Yellow house	2020-06-04	0.75	0.19
FVRD-113	Wilbourne Road	2020-06-04	1.50	0.38
FVRD-113	Wilbourne Road	2020-06-04	1.50	0.38
FVRD-111	Gill Road	2020-06-04	0.50	0.13
FVRD-110	Camp Slough	2020-06-04	2.00	0.50
FVRD-109	End of Edmonson Road	2020-06-04	9.00	2.25
FVRD-194	Hope golf course active channels	2020-06-04	6.00	1.50
FVRD-260	Seabird ditch	2020-06-05	5.00	1.25
FVRD-136	Seabird Road Island at Powerlines	2020-06-05	9.00	2.25
FVRD-116	Ferry Road	2020-06-05	1.50	0.38
FVRD-063	Island 22	2020-06-05	33.00	8.25
	Cheam Campground	2020-06-05	5.00	1.25
	Cheam Campground	2020-06-05	12.00	3.00
	Cheam Campground	2020-06-05	6.00	1.50
FVRD-068	Sandpiper	2020-06-05	3.00	0.75
FVRD-002	Glen Valley Poplar Bar - West	2020-06-06	0.50	0.13
FVRD-004	Glen Valley Poplar Bar - East	2020-06-06	1.50	0.38
FVRD-003	Glen Valley Poplar Bar entrance	2020-06-06	1.00	0.25
FVRD-058	Skway First Nations South	2020-06-07	1.50	0.38
FVRD-018	Matsqui	2020-06-07	5.00	1.25
FVRD-226	Skway North	2020-06-07	1.00	0.25
FVRD-222	Skway FN channel	2020-06-07	1.00	0.25
FVRD-023	Dyke site- Hyde Road	2020-06-08	6.00	1.50
FVRD-089	Ballam Ditch	2020-06-08	12.00	3.00
FVRD-077	Ballam Pond	2020-06-08	2.00	0.50
FVRD-225	end of newton Road	2020-06-09	12.00	3.00

Site Code	Site Name	Treatment Date	Treatment Amount (Kg)	Treated Area (Ha)
FVRD-098	Kitchen Hall Road	2020-06-09	3.00	0.75
FVRD-190	Rotary by chinook	2020-06-09	1.50	0.38
FVRD-206	Allendales Farm Channels	2020-06-09	7.50	1.88
FVRD-136	Seabird Road Island at Powerlines	2020-06-10	6.00	1.50
FVRD-260	Seabird ditch	2020-06-10	3.00	0.75
FVRD-260	Seabird ditch	2020-06-10	5.00	1.25
FVRD-260	Seabird ditch	2020-06-10	5.00	1.25
FVRD-260	Seabird ditch	2020-06-10	5.00	1.25
FVRD-054	Dyke Road east	2020-06-10	6.00	1.50
FVRD-104	Camp River Road House	2020-06-10	10.50	2.63
FVRD-100	Carey Road Field	2020-06-10	1.50	0.38
FVRD-101	Jesperson Road	2020-06-10	1.50	0.38
FVRD-091	McSween Ditch	2020-06-10	13.00	3.25
FVRD-086	Bell and McSween	2020-06-10	1.50	0.38
FVRD-191	Chehalis Reserve	2020-06-11	6.00	1.50
FVRD-113	Wilbourne Road	2020-06-11	1.00	0.25
FVRD-111	Gill Road	2020-06-11	0.50	0.13
FVRD-110	Camp Slough	2020-06-11	3.00	0.75
FVRD-107	Camp River slough	2020-06-11	1.00	0.25
FVRD-172	Wild rose	2020-06-12	1.00	0.25
FVRD-180	Landstrom Road	2020-06-12	5.00	1.25
	Cheam Campground	2020-06-12	12.00	3.00
FVRD-116	Ferry Road	2020-06-12	5.00	1.25
FVRD-066	Cartmell Road	2020-06-12	2.00	0.50
FVRD-063	Island 22	2020-06-12	11.50	2.88
FVRD-061	C4	2020-06-14	0.50	0.13
FVRD-227	Skway bulldozer path	2020-06-14	1.50	0.38
	Matsqui trail	2020-06-15	3.00	0.75
FVRD-089	Ballam Ditch	2020-06-15	12.00	3.00
FVRD-232	Paul's house	2020-06-16	6.00	1.50
FVRD-023	Dyke site- Hyde Road	2020-06-16	6.00	1.50
FVRD-190	Rotary by chinook	2020-06-16	2.00	0.50
FVRD-104	Camp River Road House	2020-06-17	11.50	2.88
FVRD-091	McSween Ditch	2020-06-17	1.00	0.25
FVRD-086	Bell and McSween	2020-06-17	1.50	0.38
FVRD-113	Wilbourne Road	2020-06-18	2.50	0.63
FVRD-111	Gill Road	2020-06-18	1.00	0.25
FVRD-110	Camp Slough	2020-06-18	3.00	0.75
FVRD-109	End of Edmonson Road	2020-06-18	1.00	0.25
FVRD-109	End of Edmonson Road	2020-06-18	5.00	1.25
FVRD-109	End of Edmonson Road	2020-06-18	7.50	1.88
	Cheam Campground	2020-06-19	3.00	0.75
FVRD-116	Ferry Road	2020-06-19	5.00	1.25
FVRD-197	Royal Wood Golf Course	2020-06-21	4.00	1.00
FVRD-227	Skway bulldozer path	2020-06-21	1.00	0.25
FVRD-095	Jess Road	2020-06-22	0.50	0.13
FVRD-089	Ballam Ditch	2020-06-22	9.00	2.25
FVRD-077	Ballam Pond	2020-06-22	2.00	0.50
	River trail	2020-06-23	6.00	1.50
FVRD-190	Rotary by chinook	2020-06-23	1.50	0.38

Site Code	Site Name	Treatment Date	Treatment Amount (Kg)	Treated Area (Ha)
FVRD-111	Gill Road	2020-06-24	0.50	0.13
FVRD-104	Camp River Road House	2020-06-24	15.50	3.88
FVRD-100	Carey Road Field	2020-06-24	1.50	0.38
FVRD-091	McSween Ditch	2020-06-24	0.50	0.13
FVRD-113	Wilbourne Road	2020-06-25	0.50	0.13
FVRD-110	Camp Slough	2020-06-25	3.00	0.75
FVRD-109	End of Edmonson Road	2020-06-25	5.50	1.38
FVRD-116	Ferry Road	2020-06-28	5.50	1.38
FVRD-063	Island 22	2020-06-28	25.50	6.38
FVRD-089	Ballam Ditch	2020-06-29	5.50	1.38
FVRD-094	End of Ballam	2020-06-29	1.00	0.25
FVRD-197	Royal Wood Golf Course	2020-06-30	4.00	1.00
FVRD-003	Glen Valley Poplar Bar entrance	2020-06-30	5.50	1.38
FVRD-058	Skway First Nations South	2020-06-30	3.00	0.75
	River trail	2020-06-30	14.00	3.50
FVRD-208	750	2020-06-30	5.50	1.38
FVRD-018	Matsqui fishing bar	2020-06-30	1.00	0.25
FVRD-233	Vedder River Campground	2020-06-30	0.50	0.13
FVRD-190	Rotary by chinook	2020-06-30	1.00	0.25
FVRD-280	Silvie's house	2020-06-30	9.00	2.25
FVRD-090	Kilby Field North	2020-06-30	31.00	7.75
FVRD-206	Allendales Farm Channels	2020-06-30	0.50	0.13
FVRD-136	Seabird Road Island at Powerlines	2020-07-01	12.00	3.00
FVRD-225	end of newton Road	2020-07-01	6.00	1.50
FVRD-023	Dyke site- Hyde Road	2020-07-01	6.00	1.50
	Cheam Campground	2020-07-02	18.00	4.50
	225 7 avenue.	2020-07-02	1.50	0.38
FVRD-194	Hope golf course active channels	2020-07-02	3.00	0.75
FVRD-104	Camp River Road House	2020-07-02	14.00	3.50
FVRD-099	End of Carey Road	2020-07-02	1.50	0.38
FVRD-100	Carey Road Field	2020-07-02	1.50	0.38
FVRD-091	McSween Ditch	2020-07-02	3.00	0.75
FVRD-086	Bell and McSween	2020-07-02	2.00	0.50
FVRD-113	Wilbourne Road	2020-07-03	4.00	1.00
FVRD-111	Gill Road	2020-07-03	1.00	0.25
FVRD-110	Camp Slough	2020-07-03	0.50	0.13
FVRD-109	End of Edmonson Road	2020-07-03	5.00	1.25
FVRD-104	Camp River Road House	2020-07-03	7.50	1.88
FVRD-227	Skway bulldozer path	2020-07-05	0.50	0.13
FVRD-116	Ferry Road	2020-07-06	4.50	1.13
FVRD-003	Glen Valley Poplar Bar entrance	2020-07-07	4.50	1.13
FVRD-197	Royal Wood Golf Course	2020-07-07	2.00	0.50
	River trail	2020-07-07	0.50	0.13
FVRD-091	McSween Ditch	2020-07-08	2.00	0.50
FVRD-091	McSween Ditch	2020-07-08	1.00	0.25
FVRD-190	Rotary by chinook	2020-07-08	1.50	0.38
FVRD-094	End of Ballam	2020-07-08	3.00	0.75
FVRD-089	Ballam Ditch	2020-07-08	4.50	1.13

Site Code	Site Name	Treatment Date	Treatment Amount (Kg)	Treated Area (Ha)
FVRD-109	End of Edmonson Road	2020-07-09	0.50	0.13
FVRD-104	Camp River Road House	2020-07-09	9.00	2.25
FVRD-099	End of Carey Road	2020-07-09	0.50	0.13
FVRD-172	Wild rose	2020-07-10	1.50	0.38
FVRD-173	Yellow house	2020-07-10	2.50	0.63
FVRD-064	Antons house	2020-07-13	12.00	3.00
FVRD-104	Camp River Road House	2020-07-13	9.00	2.25
FVRD-094	End of Ballam	2020-07-13	4.50	1.13
FVRD-089	Ballam Ditch	2020-07-13	7.50	1.88
FVRD-190	Rotary by chinook	2020-07-13	1.50	0.38
FVRD-116	Ferry Road	2020-07-13	3.00	0.75
FVRD-208	750	2020-07-13	2.00	0.50
FVRD-208	750	2020-07-13	3.00	0.75
FVRD-004	Glen Valley Poplar Bar - East	2020-07-13	1.00	0.25
FVRD-227	Skway bulldozer path	2020-07-13	0.50	0.13
FVRD-058	Skway First Nations South	2020-07-13	3.00	0.75
FVRD-044	C1	2020-07-13	1.00	0.25
FVRD-197	Royal Wood Golf Course	2020-07-13	4.50	1.13
FVRD-280	Silvie's house	2020-07-17	6.00	1.50
FVRD-111	Gill Road	2020-07-17	1.50	0.38
FVRD-110	Camp Slough	2020-07-17	3.00	0.75
FVRD-109	End of Edmonson Road	2020-07-17	3.00	0.75
FVRD-091	McSween Ditch	2020-07-17	2.00	0.50
FVRD-197	Royal Wood Golf Course	2020-07-19	6.00	1.50
FVRD-208	750	2020-07-19	6.00	1.50
FVRD-190	Rotary by chinook	2020-07-20	2.00	0.50
FVRD-104	Camp River Road House	2020-07-20	4.50	1.13
FVRD-116	Ferry Road	2020-07-20	2.00	0.50
FVRD-094	End of Ballam	2020-07-24	3.00	0.75
FVRD-104	Camp River Road House	2020-07-24	4.50	1.13
FVRD-208	750	2020-07-26	3.00	0.75
FVRD-208	750	2020-07-26	3.00	0.75
FVRD-197	Royal Wood Golf Course	2020-07-26	3.00	0.75
FVRD-058	Skway First Nations South	2020-07-26	1.50	0.38
FVRD-109	End of Edmonson Road	2020-07-27	1.00	0.25
FVRD-190	Rotary by chinook	2020-07-27	1.00	0.25
FVRD-116	Ferry Road	2020-07-27	3.00	0.75
FVRD-100	Carey Road Field	2020-07-31	1.00	0.25
FVRD-094	End of Ballam	2020-07-31	2.50	0.63
FVRD-089	Ballam Ditch	2020-07-31	4.00	1.00
FVRD-104	Camp River Road House	2020-07-31	4.50	1.13
FVRD-208	750	2020-08-02	7.00	1.75
FVRD-110	Camp Slough	2020-08-04	1.50	0.38
FVRD-116	Ferry Road	2020-08-04	1.50	0.38
FVRD-116	Ferry Road	2020-08-10	4.50	1.13
FVRD-190	Rotary by chinook	2020-08-10	1.00	0.25
FVRD-094	End of Ballam	2020-08-14	0.50	0.13
FVRD-113	Wilbourne Road	2020-08-14	1.00	0.25
FVRD-109	End of Edmonson Road	2020-08-14	2.00	0.50
FVRD-190	Rotary by chinook	2020-08-17	1.00	0.25

III-B: Aerial Treatments

Sites	Treatment Date	Amount Applied (Kg)	Amount Applied (Ml)	Area Treated (Ha)
Mi-7	2020-05-15	200.20		20.02
Comrey C	2020-05-15	546.00		54.60
Stave Lake	2020-05-28		30000	30.00
Ballam Pond,Carey Island,Mouth of Harrison,Wentworth's Field,Vasha's House,Stilts house	2020-05-30	1310.40		131.04
C4,Allendales Farm Channels,Island 22,Comrey C	2020-05-30	800.80		80.08
Matsqui fishing bar,Mouth of Nicomen Slough,Lackaway,Barrowtown	2020-05-30	1710.80		171.08
Crescent Island,Brae Island Park / Fort Camping	2020-05-30	72.80		7.28
Matsqui Island,Mission raceway	2020-05-30	691.60		69.16
Blue ridge Ranch,Hayward & Caignou Slough	2020-06-01	109.20		10.92
Herrling Island	2020-06-01	1820.00		182.00
Seabird Island Road South,Seabird Road Island at Powerlines,Seabird ditch	2020-06-01	546.00		54.60
Seabird ditch	2020-06-01	72.80		7.28
Peters road	2020-06-01	72.80		7.28
Ruby Field,Skowahlook First Nations,St Elmo Rd	2020-06-01	109.20		10.92
Hope golf course active channels,Landstrom Road,Bristol Island,Chawathil active ditch west site	2020-06-01	327.60		32.76
Herrling Island,Deeper channel right side of road pathway,Seabird Island Road South,Peters road	2020-06-10	873.60		87.36
Carey Island,Stilts house,Vasha's House	2020-06-10	1001.00		100.10
Island 22,Comrey C,Allendales Farm Channels	2020-06-10	873.60		87.36
Matsqui fishing bar,Mouth of Nicomen Slough,Thompson road	2020-06-11	473.20		47.32
Crescent Island,Mi-7,Mission raceway	2020-06-11	400.40		40.04
Hope golf course active channels,Chawathil active ditch west site,Drive way	2020-06-12	236.60		23.66
Stave Lake	2020-06-19		40000	40.00
Carey Island	2020-07-01	254.80		25.48
Mouth of Harrison,Wentworth's Field	2020-07-01	218.40		21.84
Comrey C	2020-07-01	254.80		25.48
Carey Island	2020-07-02	254.80		25.48
Mi-7,Mission raceway	2020-07-02	1292.20		129.22
Lackaway	2020-07-02	327.60		32.76
Island 22,Comrey C,Allendales Farm Channels	2020-07-02	891.80		89.18
Creek access point,Seepage FN Site	2020-07-03	72.80		7.28
Mi-7	2020-07-03	91.00		9.10
Hayward & Caignou Slough,Blue ridge Ranch,Herrling Island,St Elmo Rd	2020-07-04	728.00		72.80
Mouth of Nicomen Slough,Upper dyke	2020-07-04	364.00		36.40
Stave Lake	2020-07-04	182.00		18.20
Stave Lake	2020-07-05	182.00		18.20

2020 Mosquito Hotline Concern Calls

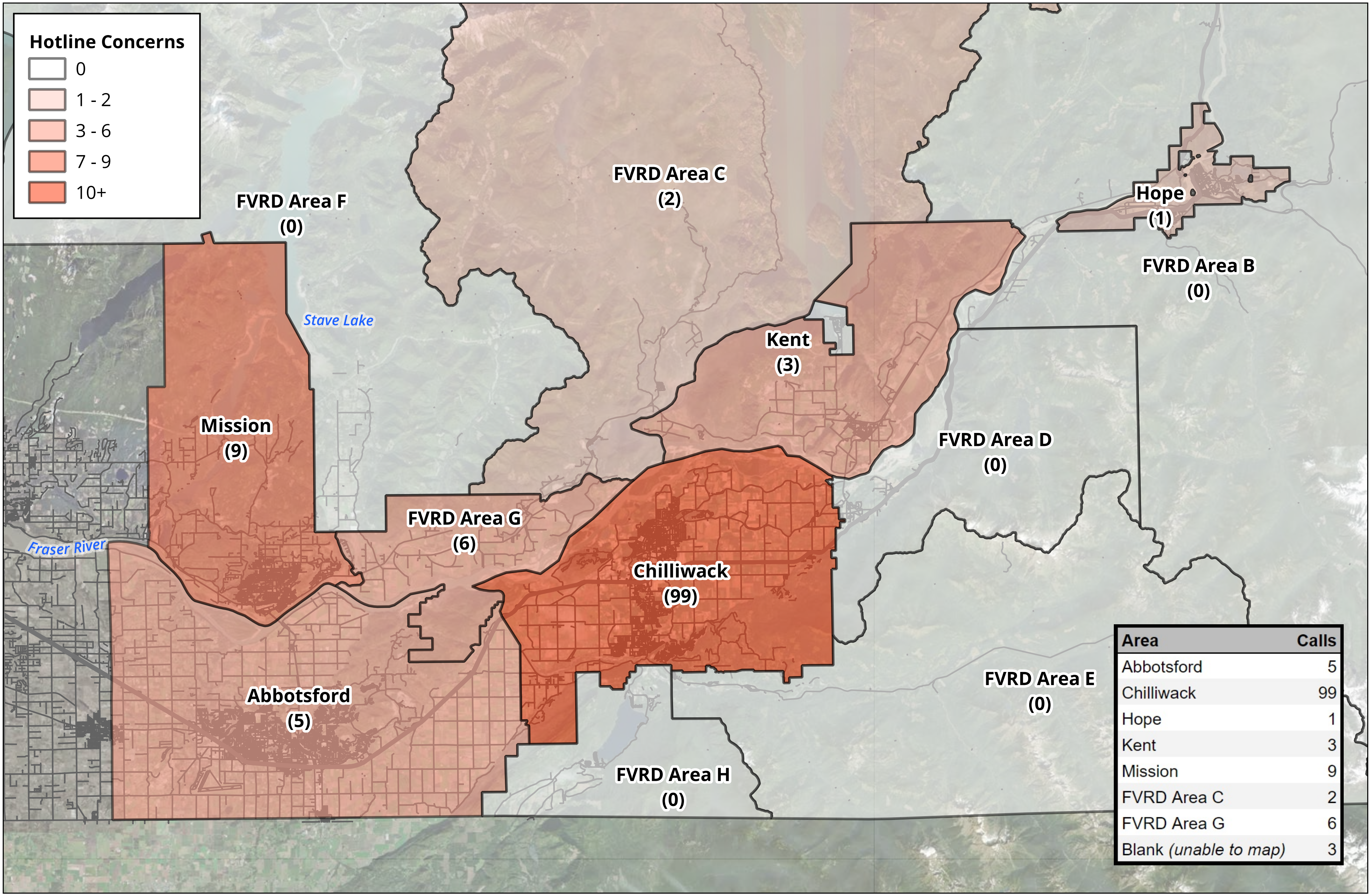
Morrow BioScience Ltd
PO Box 1013 Rossland, BC V0G 1Y0
gis@morrowbioscience.com 1(877)986-3363

Appendix IV

0 10 20 km

Scale = 1 : 150,000 CRS = NAD83 UTM Zone 10N

N



Area	Calls
Abbotsford	5
Chilliwack	99
Hope	1
Kent	3
Mission	9
FVRD Area C	2
FVRD Area G	6
Blank *(unable to map)*	3

Frequently Asked Questions

Floodwater Mosquito Biology and Disease Transmission

MorrowBioScience Ltd.

Updated: 3 May 2020

Updated: 3 May 2020

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Category 1: Mosquito Ecology

Question 1: What type of mosquitoes are controlled by Morrow BioScience Ltd (MBL)?

Most mosquito control program operated by MBL focus on one complex of mosquitoes, those that develop in floodwaters, primarily during the Spring freshet (e.g. Aedes vexans, Aedes sticticus). However, certain programs within BC also have snowmelt mosquito species (e.g. Aedes communis). The females of these snowmelt species lay eggs in depressions within the landscape that allow for snowmelt or precipitation to accumulate. Eggs are able to hatch under considerably cooler conditions than those of floodwater or container mosquito species. At this time, MBL does not control mosquito species typically found in containers (e.g. Culex pipiens).

Question 2: Why doesn't MBL control container mosquitoes like those in residential backyards and catch basins?

At this time, MBL doesn't focus on treating containers (i.e. catch basins, bird baths, gutters, old tires, etc.) to control container mosquito species primarily because most of the container mosquito development sites are located on private property. While sometimes producing enough mosquitoes to create very localized annoyance, they don't create broader nuisance levels. Although MBL doesn't specifically target container mosquitoes, field and outreach staff have developed messaging aimed at informing residents of proactive measures that can reduce container mosquito habitat around their homes. Measures include refreshing stagnant water daily during the height of the season, ensuring gutters are cleaned and not holding water, removing old tires, covering rain barrels with a fine mesh to prevent mosquitoes from accessing, and many more.

Question 3: What conditions need to be present for floodwater mosquitoes to hatch?

Floodwater mosquito eggs are triggered to hatch when submerged by fresh floodwaters, typically occurring as a result of the Spring freshet in BC. As water warms up in the late spring, larvae develop faster.

Question 4: What environmental factors in BC govern floodwater mosquito development?

Tracking environmental factors that affect the flooding capacity within an area is important. Flooding in BC typically occurs in the Spring as a result of the Spring freshet from snow basins contributing to local rivers. Snowpacks vary inter-annually. When snowpacks in contributing basins are low, the freshet usually follows suit and when they are high, the freshet is comparatively high. A high freshet means more mosquito eggs may be activated to hatch, *especially if previous seasons' freshets resulted in low local river levels. Snowpacks in BC are assessed by automated snow weather stations throughout the year and can be found at: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-science-data/water-data-tools/snow-survey-data.*

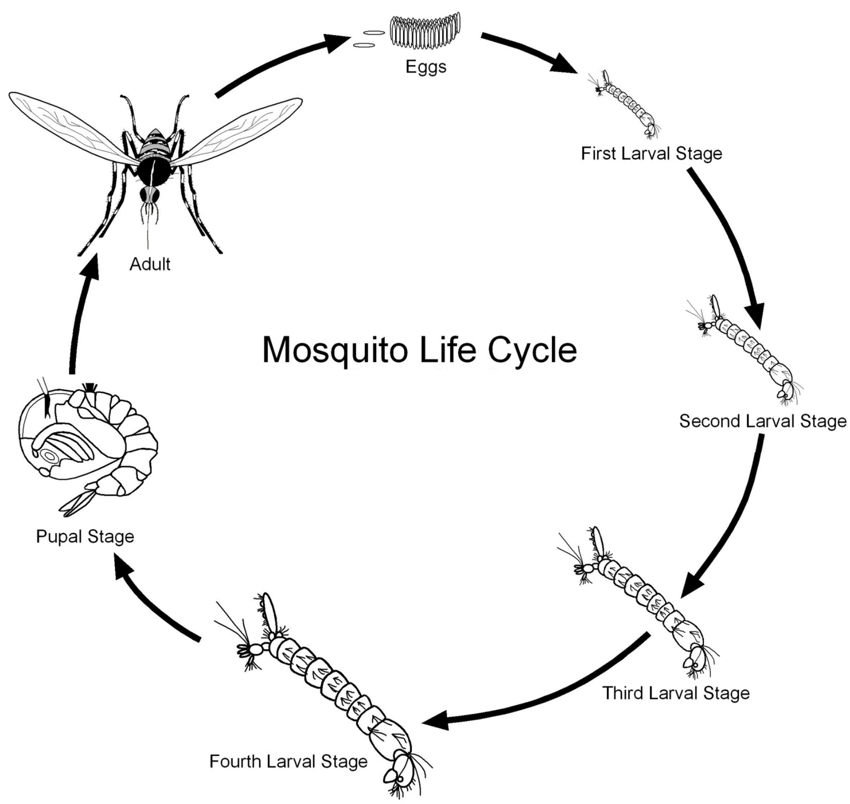
Significant local precipitation accumulation may also elevate local river levels. Local precipitation can temporarily increase seepage site levels, where mosquito development habitat is located. Thus, tracking local precipitation accumulation can aid MBL field staff with determining how long mosquito development sites may require management. Local weather station data can be found at: https://climate.weather.gc.ca

Question 5: Why are adult mosquitoes most abundant after the peak in local rivers?

Peak river levels represent the time at which the majority of floodwater mosquito eggs have been triggered to hatch for the season. The time from when an egg hatches to emergence and dispersal is typically 2-3 weeks (although this is highly dependent upon water temperatures). So even as local river levels are receding, mosquito development may still be taking place. Adult floodwater mosquitoes are strong enough to disperse from their hatch site quickly and are able to fly multiple kilometers in search of a blood meal. Significantly warm weather increases the rate at which a mosquito develops and may lead to more aggressive activity toward the end of a mosquito's lifespan.

Category 2: Mosquito Development

Question 1: What is the lifecycle of floodwater mosquito species within the program area?



Source: North Shore Mosquito Abatement District (https://www.nsmad.com)

Floodwater mosquito eggs are laid in the damp substrate along floodwater corridors. Flooding along with other appropriate environmental triggers (i.e. sufficiently warm, low dissolved oxygen) allow for the eggs to hatch into larvae. The larvae go through four aquatic instar stages, which are also the primary feeding stages, prior to developing into pupae. Pupae then emerge into adults. The development process can take as little as four days in some species and conditions to as long as two weeks. Development times also depend on ambient and aquatic temperature, with warmer water resulting in accelerated mosquito development.

Question 2: At what life stage are mosquitoes targeted for control?

MBL does not conduct adult mosquito control. Adult control requires the use of pesticides with considerable indirect and non-target effects. Instead, MBL targets the larval stage of the mosquito. Mosquito larvae are the feeding stage of the life cycle, which makes the larval instars particularly susceptible to larvicides dependent on ingestion. Specifically, the 3rd and early 4th *larval instars are the target of MBL's floodwater mosquito control program. Larvicides are more effective in the latter instar stages and earlier instar stages are left as biomass for the aquatic food web.*

Question 3: How far can mosquitoes fly from their hatch site?

Maximum flight distance from hatch site varies widely dependent upon species. A common floodwater, Aedes vexans, may fly greater than 4 km from their hatch site, on average. The main implication of these data is that uncontrolled mosquitoes may impact people from distances farther than 4 km, in some circumstances. MBL endeavours to reduce mosquito annoyance to residents in all areas within the contract purview.

Category 3: Disease Transmission

Question 1: What diseases can mosquitoes transmit in Canada?

In Canada, mosquitoes have been shown to transmit West Nile virus, Eastern Equine encephalitis virus, and California serogroup viruses. West Nile virus is the most widely distributed vector borne disease in North America. As the climate in Canada becomes warmer, the environment is more hospitable to additional vectors and associated viruses.

Question 2: Is West Nile virus a concern in BC? What are the most recent levels?

West Nile virus (WNv) is only a slight concern in BC given the relatively few number of mosquito pools, birds, horses, and humans who have tested positive. From 1 January – 12 October 2019, one positive human WNv case was detected in BC. In that same year no animals, no mosquito pools, and no birds tested positive for the virus. Certain container mosquitoes, such as Culex pipiens and Culex tarsalis, are primary WNv vectors. In warmer seasons, more container mosquito breeding occurs, leading to greater potential for WNv transmission.

To reduce WNv exposure through mosquitoes, MBL and the BC Centre for Disease Control urges residents to:

- *remove or refresh standing water daily in the warmer months,*
- *ensure that outdoor plants or containers have a drainage hole,*
- *clear rain gutters of debris and make sure they drain,*
- *turn over wading pools when not in use, and*
- *install screens on windows and doors.*

Question 3: Where can I go to find more information about West Nile virus?

Health Canada maintains a thorough surveillance website, organizing cases by type (i.e. human, animal, mosquito), week, and province from mid-April through October. The Health Canada site also provides health-specific information surrounding WNv. It can be found at: [*https://www.canada.ca/en/public-health/services/diseases/west-nile-virus.html*](https://www.canada.ca/en/public-health/services/diseases/west-nile-virus.html)

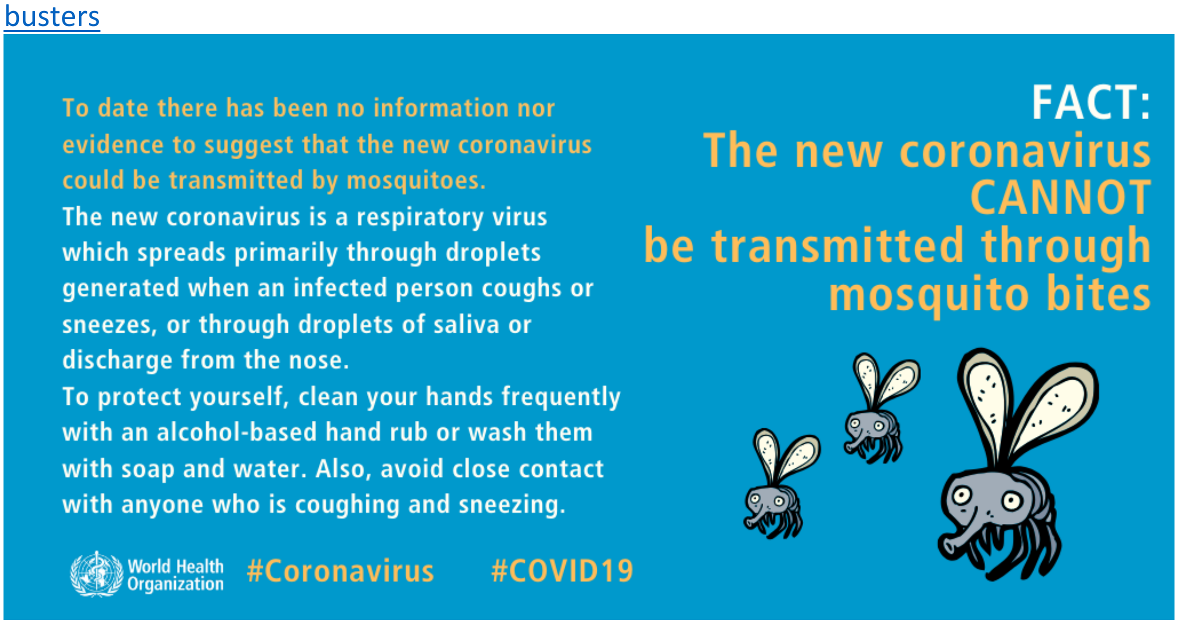
The BC Centre for Disease Control (BCCDC) website also contains health-related information for residents. The BCCDC site has a more detailed map of surveillance activity by region. It can be found at: http://www.bccdc.ca/health-info/diseases-conditions/west-nile-virus-wnv

Question 4: Can mosquitoes act as a vector for COVID-19?

At this time, there is no evidence that mosquitoes are involved in the spread of COVID-19 (SARS-CoV-2). It is thought that the COVID-19 virus may not survive the internal processes of the mosquito. Other supportive evidence for the inability of mosquitoes to act as vectors COVID-19 is that other Coronaviruses have not proven transmissible through mosquitoes.

Question 5: Where can I go to learn more about the potential for mosquitoes to transmit COVID-19?

The Center for Disease Control addresses the potential for vectorization of COVID-19 in mosquitoes: [*https://www.cdc.gov/coronavirus/2019-ncov/faq.html*](https://www.cdc.gov/coronavirus/2019-ncov/faq.html)
The World Health Organization also addresses this question:
https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public/myth-busters



References

Belton, P. (1983). The Mosquitoes of British Columbia. British Columbia Provincial Museum, Victoria, British Columbia, Canada.

Center for Disease Control. (2020). Coronavirus Disease 2019 (COVID-19), Frequently Asked Questions. Available online: https://www.cdc.gov/coronavirus/2019-ncov/faq.html

Health Canada. (2018). West Nile Virus and Other Mosquito-Borne Diseases National Surveillance Report. Available online: https://www.canada.ca/en/public-health/services/diseases/west-nile-virus/west-nile-virus-other-mosquito-borne-disease.html

Trpis, M. and Horsfall, W.R. (1969). Development of *Aedes sticticus* (Meigen)) in Relation to Temperature, Diet, Density, Depth. Annals Zoologici Fennici, 6(2): 156-160.

Verdonschot, P. F.M. and Besse-Lotoskaya, A. A. (2014). Flight Distance of Mosquitoes (Culicidae): A Metadata Analysis to Support the Management of Barrier Zones Around Rewetted and Newly Constructed Wetlands. Limnologica 45 (2014): 69-79.

Wood, D.M., Dang, P.T., and Ellis, R.A. (1979). *The Insects and Arachnids of Canada* (Part 6). Ottawa, Canada.

World Health Organization. (2020). Coronavirus Disease (COVID-19) Advice for the Public: Myth Busters. Available online: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public/myth-busters

Frequently Asked Questions

Bacillus thuringiensis var. *israelensis* (Bti) Bacterial Larvicide

MorrowBioScience Ltd.

Updated: 3 May 2020

MorrowBioScience Ltd

Updated: 3 May 2020

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Updated: 3 May 2020

Category 1: Operations and Treatment Need

Question 1: Why do we use a larvicide product to control mosquitoes?

Most mosquito control programs focus on one complex of mosquitoes, those that develop in floodwaters, primarily during the Spring freshet. These mosquitoes come out in areas where predation is relatively low, and in numbers that overwhelm the ecosystem. Appropriately conducted larval controls can significantly reduce the severity and duration of these infestations.

Mosquito control products primarily target the larval (aquatic) or adult stages of the mosquito lifecycle. Controlling mosquitoes in the larval stage before they emerge as adults better focuses treatment, as larval mosquitoes are located within a more predictable and confined area than adult mosquitoes. Fewer treatments are required if they are timed appropriately, reducing program costs and environmental impact of treatment. Finally, the bacterial larvicides utilized by MBL have considerably fewer non-target and indirect effects associated with inadvertent exposure than adult mosquito control pesticides.

Question 2: How are bacterial larvicides different from other pesticides?

The larval control product utilized by Morrow BioScience Ltd. (MBL) certified pesticide applicators is Aquabac®. The active ingredient is a soil-borne bacterium, Bacillus thuringiensis var. *israelensis (Bti). The efficacy of Bti relies upon the natural bacterium and associated toxin protein to be ingested by the mosquitoes. The toxin protein requires four specific receptors found within the gut of mosquitoes to activate the toxin. With few exceptions within the Dipteran taxa, the four receptors found within mosquitoes are lacking in other taxa. Thus, the Bti is considered non-toxic to, fish, amphibians, reptiles, mammals, and most insects.*

The non-target and/or indirect effects of other mosquito control products, however, are almost all higher. For example, adult mosquito control products with malathion inhibit cholinesterase, which is a neurotransmitter enzyme. As such, non-target or indirect exposure to this active ingredient can be toxic to other aquatic organisms, birds, and mammals. The mode of action for Bti is relatively simple and with a high degree of species specificity. Receptors within the mid-gut region of the mosquito larvae are specific to the toxin proteins that are produced alongside each bacterial spore. After the mosquito larvae ingest the toxin protein, disruption of the larval mid-gut cells occurs because of cleavage of the protoxins by mid-gut proteases. This event causes considerable damage to the wall of the gut and quickly leads to larval death (Boisvert and Boisvert 2000).

Question 3: What is involved in this type of treatment?

Morrow BioScience Ltd. (MBL) certified technicians conduct site larval monitoring prior to treatment. Bti treatments target the 3rd instar stages to target the primary feeding stages and to leave early instar larvae as food for others within the ecosystem. Treatments are conducted in compliance with the IPM Act. Larvicide will be applied via hand, a backpack sprayer, or helicopter as determined by the qualified MBL technician. Aerial treatment notices will be posted and will remain on site for a minimum of 1 week. The posted public notice will include the following information:

- *The trade name and active ingredient of the larvicide;*
- *The date and time of the larvicide treatment;*
- *The purpose of the treatment;*
- *Precautions to be taken to prevent harm to people entering the treatment area;*
- *The PMP confirmation number and*
- *The contractor's contact information.*

Question 4: Can I do this on my own property?

Residential mosquito control products are available for purchase at local stores. The use of commercial pesticides on private land now requires a Residential Applicator Certificate (RAC). Residents do not require a RAC to use Domestic class pesticides on their property. Residents can apply pesticides listed on Schedule 2 and 5 without a RAC. The RAC is free to obtain on-line, see www.mytrainingbc.ca/homepesiticideuse/ for more information.

It is extremely important that residential treatments ONLY occur in self-contained and man-made bodies of water. This could include constructed ornamental ponds, un-used pools, or other reservoirs located and constructed solely on the related property. Water bodies that are connected to a natural environment should be reported to local authorities who can assess the need for, and appropriateness of, treatments.

Question 5: Where are the Aquabac® treatments applied?

Aquabac® (*Bti) treatments may be applied within the client's purview, with compliance to the product label, provincial legislation, and regional legislation. These treatments primarily take place in floodwaters associated with the freshet.*

Question 6: Do land owners have the right to refuse Aquabac® treatments?

Land owners have the right to refuse access.

Question 7: I do not want/will not allow Aquabac® treatments on my property, are there any alternatives?

The most effective control method for mosquitoes around a residence is to reduce, remove, or refresh standing water where mosquitoes can breed. Specifically:

- *Empty water in old tires, buckets, toys, and flower pots*
- *Refresh water in bird baths, fountains, wading pools and animal dishes at least every 3 days*
- *Clean roof gutters and ensure proper drainage*
- *Fix leaky sprinklers and outside faucets*

Question 8: When Aquabac® is applied by helicopter in high traffic areas, how will residents be warned?

Treatment notices will be posted prior to treatment and will remain on site for a minimum of 1 week. The posted public notice will include the following information:

- *The trade name and active ingredient of the larvicide;*
- *The date and time of the larvicide treatment;*
- *The purpose of the treatment;*
- *Precautions to be taken to prevent harm to people entering the treatment area;*
- *The PMP confirmation number and*
- *The plan holder(s) contact information.*

Question 9: How is Aquabac® applied?

MBL qualified technicians use back pack blowers and helicopters to apply Aquabac®.

Question 10: How long does it take for Aquabac® to have an effect on larval mosquitoes?

- *Larval mosquitoes are affected within hours of Aquabac® exposure.*
- *Within 48 hours, the efficacy rate is between 85-100%.*

Category 2: Personal Non-Target Effects

Question 1: Will Aquabac® (Bti) harm my pets?

- *Because Bti targets certain larval Dipteran species (mosquitoes, biting flies, fungus gnats), it is highly unlikely that pets will be harmed from Bti exposure.*
- *When tested on lab animals, acute oral and dermal LD_{50}s (median lethal dosage where 50% of the test subjects are killed) were all greater than the highest dosages tested. These dosages are far greater than those likely to be experienced in the field.*

Question 2: Could Aquabac® treatments harm humans?

Toxicological studies indicate an extremely low toxicity profile where test animals are concerned (See Question 1, above). To be registered for use in Canada, products must be proven to be non-toxic to test animals at label-specified application rates. Allowable human exposure rates are 10-fold less than the No Observed Adverse Effect Levels (NOAEL) established for test animals, leaving a large buffer for potential inter-species differences between test animals and humans.

Question 3: How far away and for what length of time should people be from Aquabac® treated sites?

Safe distances for the public to maintain are suggested during aerial treatments to avoid being hit by small corn granules impregnated with Bti spores. However, there is no toxicity-based reason to avoid the area. Additionally, there is no restricted-entry interval (REI) for microbial pesticides, such as Bti. As such, the public may be in the treatment area during back-pack application or immediately following aerial application.

Category 3: Environmental Effects

Question 1: How does Aquabac® directly affect non-target aquatic invertebrates, fishes, terrestrial invertebrates, birds, and terrestrial vertebrates?

- *Aquatic organisms: Aquatic organisms (non-target inverts & fishes) are generally not affected by Bti exposure.*
- *Terrestrial invertebrates: Bti is considered non-toxic to the majority of terrestrial invertebrates. However, certain studies have shown impacts on some Lepidoptera (butterfly) when in their larval form and some Nematode eggs (although certain Nematode species' eggs increased following Bti exposure). It is important to consider the low likelihood that Lepidoptera larvae will be exposed to Bti at the rate required to illicit negative impacts.*
- *Birds: No toxic effects with exposure tests.*
- *Terrestrial vertebrates: Toxicity tests on lab animals, acute oral and dermal LD_{50}s (median lethal dosage where 50% of the test subjects are killed) were all greater than the highest dosages tested. These dosages are far greater than those likely to be experienced in the field.*

Question 2: How long does Aquabac® remain active in the water?

The field half-life for Bti in water ranges from approximately 4 hours to 5 months, depending on UV exposure and organic content of the water. The higher the UV exposure, the shorter the half-life. The higher the organic content, the longer the half-life. The great majority of Bti spores will become ineffective within 24 hours of application in a field setting using Aquabac® - the primary product utilized by MBL. Other products may allow for Bti spores to be continuously released in the water column for up to 30 days.

Question 3: What is the soil half-life of Aquabac®?

Bti is a soil-borne bacterium, so is naturally found in soil environments. However, in its active form, it can persist for months in basic soil conditions. Bti's toxin proteins are rapidly broken down in soils with a pH < 5.1.

Question 4: What is the mode of action for Aquabac® (Bti)?

The mode of action for Bti is relatively simple and with a high degree of species specificity. Receptors within the mid-gut region of the mosquito larvae are specific to the toxin proteins that are produced alongside each bacterial spore. After the mosquito larvae ingest the toxin protein, disruption of the larval mid-gut cells occurs because of cleavage of the protoxins by mid-gut proteases. This event causes considerable damage to the wall of the gut and quickly leads to larval death (Boisvert and Boisvert 2000).

Question 5: If I notice any effects that I think might be connected to an Aquabac® treatment, who should I contact?

Should an individual feel that they, or their pet, have been affected by a treatment, then they should see their doctor. It is extremely unlikely that any malady is related to the treatment, but worth seeing a certified medical practitioner for clarification (and to determine what the cause may be so a treatment can be offered). The affected individual needs to have information about the application from the contract applicator (product name, where the larvicide was applied, when, etc.). If more information is needed, then they should contact the Operations Program Coordinator at MBL for specific information surrounding the potential indirect or non-target effects of the larvicide. If the person wishes to contact someone beyond MBL, they should be directed to contact Health Canada and report a pesticide incident. If a sufficient amount of information has been provided, Health Canada can determine whether or not the effect is due to that product's exposure. The forms can be found at: http://www.hc-sc.gc.ca/cps-spc/pest/part/protect-proteger/incident/index-eng.php

Category 4: Registration and Permitting

Question 1: Who registers pesticide products in Canada?

- The Pest Management Regulatory Agency regulates all pesticides and pesticide applications in Canada under the Pest Control Products Act.

Question 2: Where can I go to get more information on the product?

- Health Canada's Public Registry has information on all registered pesticides and the pesticide regulatory system. https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management/public/protecting-your-health-environment/public-registry.html

References

Joung, KB and Cote, JC. 2000. A review of the environmental impacts of the microbial insecticide *Bacillus thuringiensis*. Agriculture and Agri-Food Canada Technical Bulletin No. 29. Cat. No. A54-9/29. Available online: http://publications.gc.ca/collections/Collection/A54-9-29E.pdf.

Aquabac® Label. 2015. Health Canada Label Search. Available online: http://pr-rp.hc-sc.gc.ca/1_1/view_label?p_ukid=125322407

Health Canada (pubs). 2013. Bti - *Bacillus thuringiensis subspecies israelensis*. Available online: https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/cps-spc/alt_formats/pdf/pubs/pest/_fact-fiche/bti-eng.pdf

Health Canada (pubs). 2018. Understanding Restricted-Entry Intervals for Pesticides. Available online: https://www.canada.ca/content/dam/hc-sc/documents/services/consumer-product-safety/reports-publications/pesticides-pest-management/fact-sheets-other-resources/fs-restricted-entry-intervals.pdf.

Boisvert, M. & Boisvert, J. 2000. Effects of *Bacillus thuringiensis* var. *israelensis* on Target and Non-Target Organisms: A Review of Laboratory and Field Experiments. *Biocontrol Sci Tech* 10, 517-561.

Pest Management Regulatory Agency (PMRA) (pubs). 2012. Malathion: Re-Evaluation Decision RVD2012-10. 54p. Available online: http://publications.gc.ca/collections/collection_2012/sc-hc/H113-28-2012-10-eng.pdf

Mosquito Disease Transmission: Just the Facts, Ma'am.

Mosquitoes are some of the most notorious disease vectors in the world. Because of their worldwide distribution (except for Antarctica), proximity to humans, and inclination to feed off of humans, mosquitoes have been able to spread viral (e.g. West Nile, Zika, Chikungunya) and parasitic (e.g. Malaria) diseases to people throughout the world. Annually, over one million human deaths are attributed to mosquito-borne diseases.

Image 1. Female Ae. aegypti mosquito getting blood meal (Credit: Bryan Reynolds/Getty Images)

But how do they do this?! It turns out female mosquitoes inject some of their own saliva into the host – humans, to name one – to stop the host's blood from coagulating before the mosquito can retrieve the blood (Image 1). If that mosquito has previously fed on a human or other animal infected with certain diseases, those diseases may have been able to replicate within the mosquito without harming it. Thus, when an infected mosquito injects saliva into a host, that host can in-turn become infected. Yikes!

So, are all viruses and parasites able to be passed from mosquitoes to humans? The short answer is no. Now for the longer answer: some viruses and parasites cannot survive the mosquito's gut (like HIV). Because of that inability, they're unable to establish within the mosquito's cells and replicate. Environmental conditions, predominantly temperature, can also affect how a capable a virus or parasite is at infecting and replicating within a mosquito. Warmer temperatures generally mean that a pathogen is able to replicate at a higher rate within a vector. Finally, the amount of the virus or parasite ingested by the mosquito also determines the ability for the mosquito to transmit the pathogen – the vector competence. The greater the dose, the greater the vector competence (assuming the pathogen is able to infect and replicate within the mosquito). The main diseases that can be transmitted by mosquitoes within Canada are the California serogroup viruses, eastern equine encephalitis, and West Nile virus (WNv). WNv is the most commonly transmitted mosquito borne disease in Canada. In 2018, a total of 432 human cases of WNv were reported in Canada – the highest total since 2007 (Image 2). Large-scale, nation-wide surveillance efforts are conducted to keep track of WNv incidence in horses, birds, and humans. These data give program managers the ability to direct mosquito control efforts.

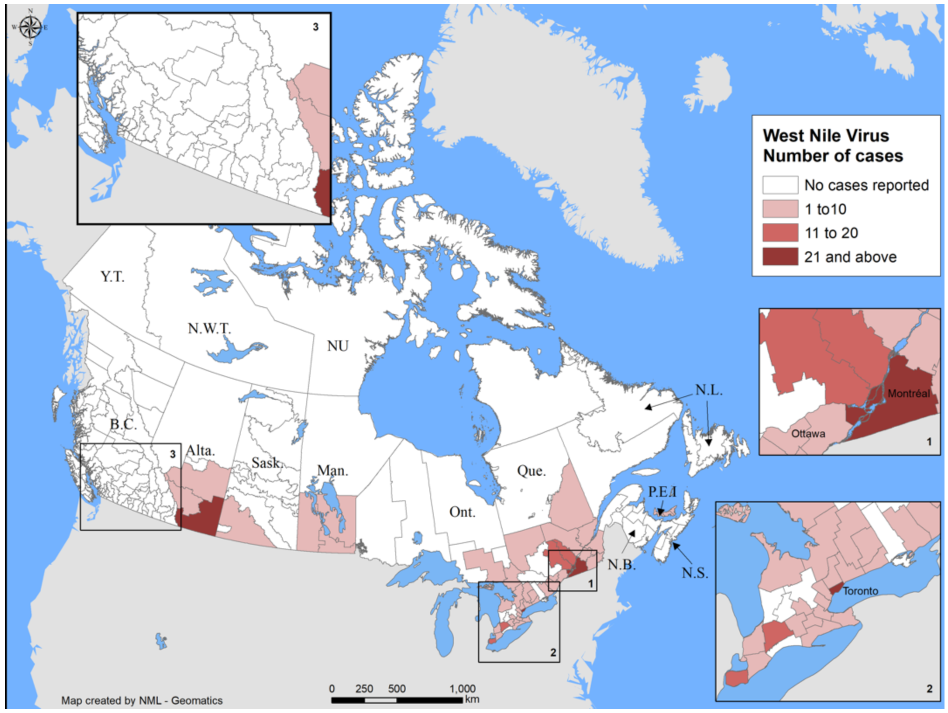

Image 2. 2018 distribution of human West Nile virus cases throughouth Canada (Health Canada)

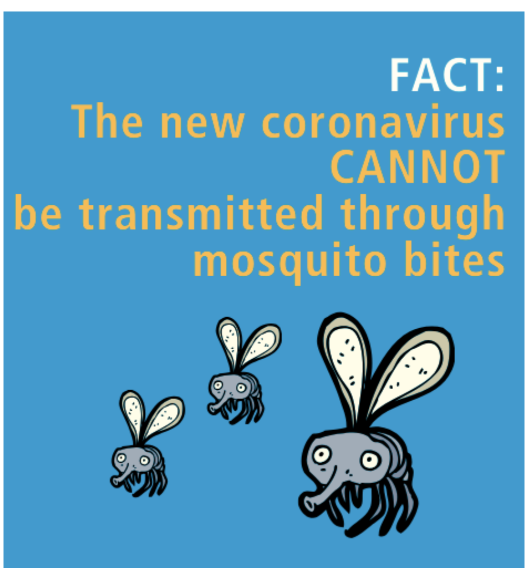

Image 3. World Health Organization myth busters

A big question on people's minds these days is whether the new coronavirus, commonly known as COVID-19, can be transmitted to humans by mosquitoes. To date, there has been **no evidence that COVID-19 can be transmitted by mosquitoes** (Image 3). It is thought that the COVID-19 virus is unable to survive the mosquito's gut to infect and ultimately replicate within the mosquito. To further support this thought, there is also no evidence that other coronaviruses (MERS, SARS) have been transmitted by mosquitoes.

Even if disease transmission is highly unlikely in BC, those bites are a nuisance! We're doing our part to help control mosquitoes in our program areas. You can help reduce mosquito habitat around your home by removing standing water (think clogged gutters, plant holders, un-used kiddy pools) or refreshing water (think bird baths, outside pet dishes/troughs) daily. Ensure all of the screens on your home are properly installed and maintained. When you're out and about, wear lightweight, long-sleeved shirts and long pants. Remember that lighter colours are less attractive to mosquitoes than are darker ones. Finally, there may be a time and a place for bug spray – we recommend bug spray with DEET.