COLUMBIA SHUSWAP REGIONAL DISTRICT
AREA 'A' – TOWN OF GOLDEN
MOSQUITO CONTROL PROGRAM
2020 YEAR-END REPORT

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Executive Summary

Morrow BioScience Ltd. (MBL) has now completed the 9th consecutive year as mosquito control contractor for Electoral Area 'A' – Town of Golden within Columbia Shuswap Regional District (CSRD). This season, 2020, concludes the 4th year of a 5-year contract. Mosquito development site knowledge has been acquired in low and high-water years and through early and late freshet seasons. The mosquito control program reduces floodwater and some snowmelt mosquito abundance within Electoral Area 'A' – Town of Golden. Most control activity takes place along the Columbia River near Donald, Blaeberry, Golden, and Nicholson.

In April, immediately preceding the mosquito season, the snowpack in the Upper Columbia basin was 113 percent of normal. A regional warming trend in early May within the Upper Columbia Basin led to the start of the mosquito season. Secondary warming stints at the end of May triggered the melting of the rest of the low and some mid-elevation snowpack, leading to the regional peak of the Kicking Horse River on 1 June (4.952 m). The Columbia River at Donald and Nicholson peaked on 28 June (4.613 m) and 30 June (3.632 m), respectively, in response to a more substantial regional melting trend in mid-June. All peaks were the highest since 2017. Regional precipitation accumulation likely did not measurably affect the Columbia River, but may have caused an extension of Kicking Horse River levels post-peak. Mosquito egg abundance compounded from previous seasons led to greater hatching in 2020. No known sites were missed in 2020, but four new wetland sites were added. Only four concern calls were received, with three additional inquiry-based calls. No human cases of West Nile virus were reported by the BCCDC in 2020.

Between 20 April and 6 July, a total of 2,912 hectares were treated by ground and helicopter. Treatment efficacy was assessed as high. Seven aerial events targeted larval mosquito development throughout the 2020 season: one (1) snowmelt-specific aerial campaign and six (6) floodwater-specific aerial campaigns. A real-time monitoring and treatment data dashboard was provided to the CSRD program manager. The dashboard enables the manager to view up-to-date treatment information and ensure quality control.

Communications with in-program residents remains a priority for MBL. Education outreach efforts included providing an interview to a local radio station focused on mosquito abatement efforts and personal protective suggestions. MBL staff also volunteered for 64 hours with Wildsight Golden to continue the promotion of environmental stewardship within MBL program purviews. The reach of social media posts continues to increase annually, meaning that more residents around Area 'A'/Golden are aware of mosquito abatement efforts and personal protective tips.

Season Highlights

- The peak Kicking Horse River level at the Golden gauge occurred on 1 June at 4.952 m.
- The peak Columbia River level at the Donald gauge occurred on 28 June at 4.613 m and at the Nicholson gauge on 30 June at 3.632 m.
- The peaks were the highest since 2017.
- The average snowpack in the Upper Columbia basin was 113 percent of normal in April, immediately preceding the onset of the mosquito season.
- A region-wide warming event within the Upper Columbia basin prompted considerable low snow melt conditions at the beginning of May, increasing Columbia River levels beyond 2.5 m on 20 May.
- One (1) aerial campaign was required to treat mountain snowmelt sites on 8 May.
- Six (6) aerial campaigns were required to treat floodwater mosquito development habitat on 5, 11, 18, 24, and 30 June and 2 July.
- Total Aquabac® ground treatments were 402 kg (105 ha).
- Total Aquabac® aerial treatments were 11,248 kg (2,812 ha).
- Hotline calls/emails were considerably low (i.e. 7 total).
- MBL's real-time data management and mapping portal provided CSRD program managers with improved ability to target areas and gave quality control assurance for clients.
- On 4 June, 104.3 FM EZRock conducted an interview with MBL's head biologist. The interview included an update on general mosquito control activities occurring within Area 'A'/Golden and personal protective measures.
- MBL staff spent 64 hours volunteering with Wildsight Golden as part of the company's commitment to promoting environmental stewardship within program purviews.

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 providers for the Electoral Area ‘A’ – Town of Golden (Area ‘A’/Golden) within the Columbia Shuswap Regional District (CSRD) since 2012. In 2017, MBL started a renewed five (5) year contract; this season – 2020 – is the fourth year of the contract.

The considerable mosquito habitat, program reach, and interannual regional river peak variations makes the Area ‘A’/Golden mosquito control program complex. However, throughout the nine (9) seasons as contractors for this program, MBL staff has acquired thorough knowledge of the area and how Area ‘A’/Golden-specific environmental conditions affect mosquito development sites. In addition to having built a program knowledge base, numerous improvements have been made to the program since its inception, including:

- intensive site survey along floodplain benches,
- identification of new mosquito development sites,
- trending decrease in complaint calls,
- the addition of a real-time data collection and review portal,
- increased public engagement both through social media, radio and 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 Area ‘A’/Golden residents, while remaining socially and environmentally responsible.

Carbon Offsets

The spatial reach of the CSRD mosquito program is such that driving is an inevitable requirement. The accumulated mileage over the course of 2020 was approximately 5,892 km (ground transportation only).

As an estimation, the driving requirements for this program result in the production of approximately 0.91 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 CSRD.

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

Methodology

The primary targets of the Area 'A'/Golden mosquito control program are floodwater mosquito larvae. Unlike container mosquitoes (e.g. *Culex pipiens*), female floodwater mosquitoes (e.g. *Aedes vexans*, *Ae. sticticus*) deposit their eggs on damp substrate. Within the CSRD, floodwater mosquito development sites primarily exist along the flooding corridors of the Columbia River and Kicking Horse River, including associated seepage sites. When water floods these sites, due to the freshet and/or significant localized precipitation, the result is large-scale floodwater mosquito egg hatching. If numerous seasons have passed between high-water years, then high river levels may trigger a compounded number of mosquito eggs to hatch.

Image 1. Standard dip with 3rd and 4th instar snowmelt larvae (April 2020)

The secondary target of the Area 'A'/Golden mosquito program is snowmelt mosquitoes. Snowmelt mosquitoes hatch early in the spring (i.e. March – April) within the area (Image 1). These sites consist of smaller depressions in the landscape where snowmelt mosquito eggs were laid the previous summer. The smaller depressions collect water in the fall and freeze. Just as the site begins to thaw, snowmelt mosquito eggs hatch. These species typically hatch early to ensure their development habitat remains wet from hatching to emergence and also to reduce inter-species habitat competition as they develop (Clements 1992). Certain snowmelt mosquito species begin to hatch at approximately 4°C water temperature and can complete development to adult emergence at 10°C (Clements 1992). Snowmelt mosquito development sites are primarily located along the mountain benches within Area 'A'.

MBL field technicians begin monitoring all known mosquito development sites within Area 'A'/Golden prior to rising Columbia River and Kicking Horse River levels in the spring or as the snowmelt sites begin to show signs of thawing. Mosquito development sites are adaptively managed, meaning that the regional river levels and local temperatures largely dictate how frequently sites are visited, as opposed to a prescribed monitoring schedule. At the height of the mosquito season, MBL staff may monitor highly productive sites multiple times a week. Adaptive management techniques allow MBL staff to most accurately time treatments, if necessary. Prescribed monitoring methods increase the risk of missing optimal treatment windows due to accelerated mosquito development rates with rising temperatures (Read and Moon 1996). Hence, as regional river levels and ambient temperatures begin to rise consistently, monitoring efforts increase.

Larval mosquitoes in sufficient number (i.e. >4/dip) are treated by ground applications of a microbial larvicide product called Aquabac®. This product has the active ingredient

Bacillus thuringiensis israelensis (Bti) and is carried in a corncob formulation. The mode of action for Bti is relatively simple and with a rather 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 due to 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).

As the season progresses and more mosquito development sites become either flooded or thawed, it becomes 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. High water years may require 2-day aerial treatment campaigns, due mostly to the level of flooding involvement associated with the Columbia River foreshore sites.

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 advanced to 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 within their ecosystem.

Sites are treated when a standard dip (350ml) collects 5 or more late instar (3rd or 4th instar) larvae per dip (Image 1). When flooding commences and ambient temperatures rise, many dips easily exceed this 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 1 or 2 days of the initial treatment to ensure treatment efficacy. If necessary, touch-up treatments are conducted.

Environmental Conditions

The three primary environmental conditions that affect floodwater or snowmelt mosquito larval production throughout the mosquito season (i.e. April – August) are: Columbia River and Kicking Horse River levels throughout the mosquito season (i.e. April – August) are: 1) local ambient temperature and ambient temperature in snow basins contributing to either the Columbia River or Kicking Horse River, 2) local precipitation, and 3) the snowpack in basins contributing to the Columbia River and Kicking Horse River near Area 'A'/Golden.

Snowpack

Floodwater mosquito abundance within Area 'A'/Golden is primarily governed by the regional Columbia River (i.e. Donald and Nicholson gauges). The Kicking Horse River also contributes water to the Columbia River near the Town of Golden, affecting down-stream flows. The water levels of those systems are governed by the freshet released from

Upper Columbia snow basin. When snowpacks within the Upper Columbia basin exceed 100 percent of normal, higher-than-average Columbia River and Kicking Horse River levels are expected during the mosquito season.

In April, immediately preceding the 2020 mosquito season, the snowpack within the Upper Columbia Basin was 113 percent of normal[2]. Ambient temperatures within the Upper Columbia Basin were cooler-than-normal. Generally, the snowpack in this basin increased slightly during April[3]. This trend is observed in the Colpitti Creek weather station (ID: 2A30P) data (Figure 1). The Colpitti Creek station is the closest weather station to Area 'A'/Golden and largely representative of other weather stations in the vicinity.

Despite a small melting event at the end of April, multiple late-season low pressure systems augmented the regional high elevation snowpack in early May and again in mid-May. A melting period took place at the end of May. Although, by that time the Snow Water Equivalent (SWE) had far exceeded the 75th percentile range for the Colpitti Creek station and many others in the area (Figure 1). This high and persistent snowpack was reflected in the 15 June Snow Survey and Water Supply Bulletin noting that the Upper Columbia Basin snowpack, as a whole, was 162 percent of normal[4]. Given the higher-than-average snowpack in the Columbia River and Kicking Horse River catchment, the associated 2020 river peaks were expected to be high.

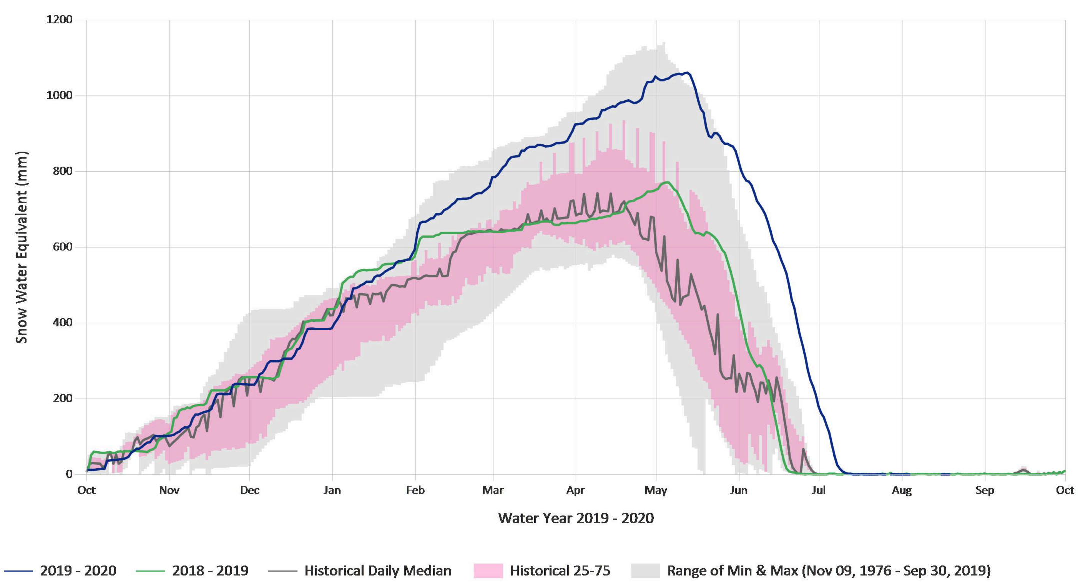

Figure 1. Snow Water Equivalent (SWE; mm) data from the Colpitti Creek snow survey (station ID: 2A30P) within the Upper Columbia Basin.

A consistent warming event began at the very end of May[5]. The warming trend resulted in the melting of most low and mid-elevation snowpack. Cooler weather occurred in the first

[2] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/river-forecast/2020_apr1.pdf
[3] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/river-forecast/2020_may1.pdf
[4] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/river-forecast/2020_june15_v10.pdf
[5] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/river-forecast/2020_june1.pdf

half of June slowing the snow melt in the Upper Columbia Basin. However, ambient temperatures within the Basin in the second half of June brought out much of the high-elevation snowpack. By the middle of July, all snow stations comprising the Upper Columbia basin had been completely depleted of snow[6].

Local Precipitation

Significant temporally and spatially concentrated precipitation accumulation may elevate regional Columbia River and Kicking Horse 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 in determining when and how long mosquito development sites may require management.

With the exception of May, the precipitation received at the Golden Airport (ID:1173220) during the 2020 mosquito season was lower than the station average (Figure 2). Thus, it is likely that precipitation did not augment regional river levels or seepage sites in those months. Precipitation accumulated in May exceeded the station average by approximately 5 mm. Although not significantly higher, the precipitation received may have been sufficient to augment local mosquito development sites and peaking regional river levels. Thus, while local precipitation may have contributed a small amount to mosquito development habitat, the primary contributor to the rising river levels was the freshet.

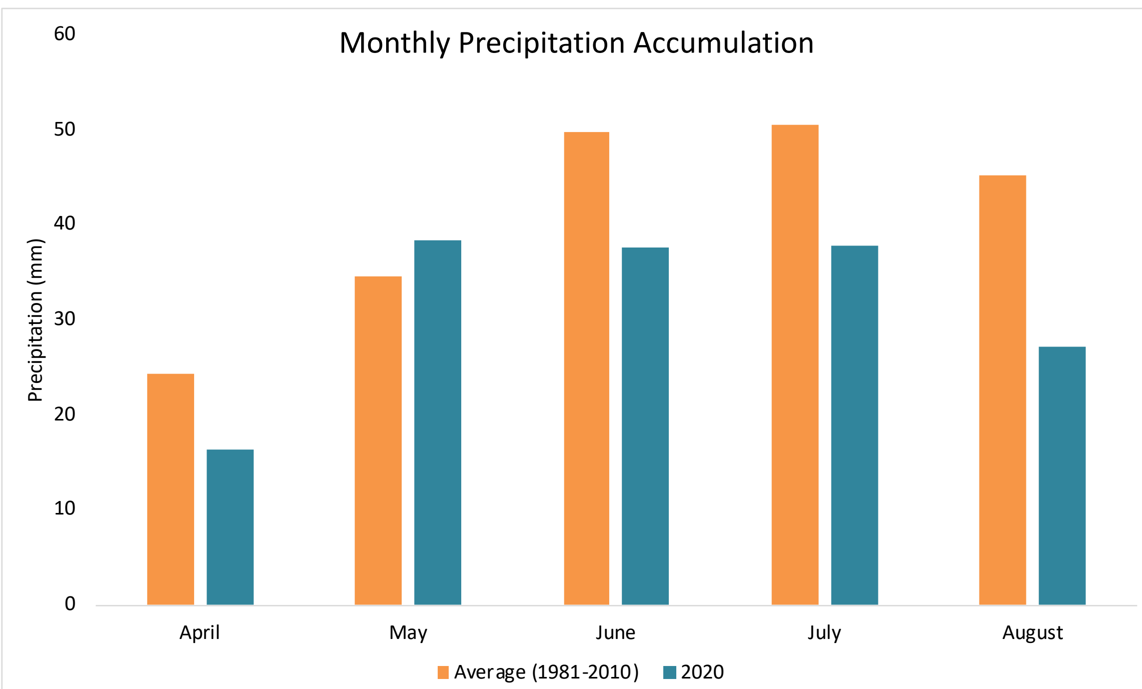

Figure 2. Precipitation values (rainfall and snow accumulation; mm) recorded at the Golden Airport weather gauge (ID: 1173220) for 01 April – 31 August 2020 (blue) and average station precipitation values (1981-2010; orange).

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

Ambient Temperature

From April through August, regional and local ambient temperature fluctuations can affect mosquito egg hatching, larval development rates, and adult dispersal rates. Ambient temperature, both locally and within the contributing snow basin, is an important environmental condition to track. The 2020 mosquito season began in April with below-normal ambient temperatures across most of the snow basin contributing to the regional Columbia River and Kicking Horse River. The below-average ambient temperatures resulted in a delay of the freshet and associated floodwater mosquito development by 2-3 weeks.

Cooler temperatures were also noted in early May within the Upper Columbia Basin. However, a ridge of high pressure in mid and late-May lent to the increased melting rate of low and some mid-elevation snowpack. High ambient temperatures were again noted in the second half of June. Ultimately, this increase in ambient temperatures in late June lead the melting of high-elevation snowpack and ultimately to the regional Columbia River peaks in 2020. Temperature data is consistent with 2020 automated snow station data[7] depicting snowmelt points correlating with regional ambient temperature spikes.

If the ground proximate to the Columbia River and Kicking Horse 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). 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. Eggs held at 21°C provided the most optimal temperature, of the five temperatures tested, for hatching and larval development (Figure 3). While *Ae. sticticus* is not the sole floodwater species present in Area 'A'/Golden, it serves as a representative species for our purposes and provides general developmental benchmarks.

[7] 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

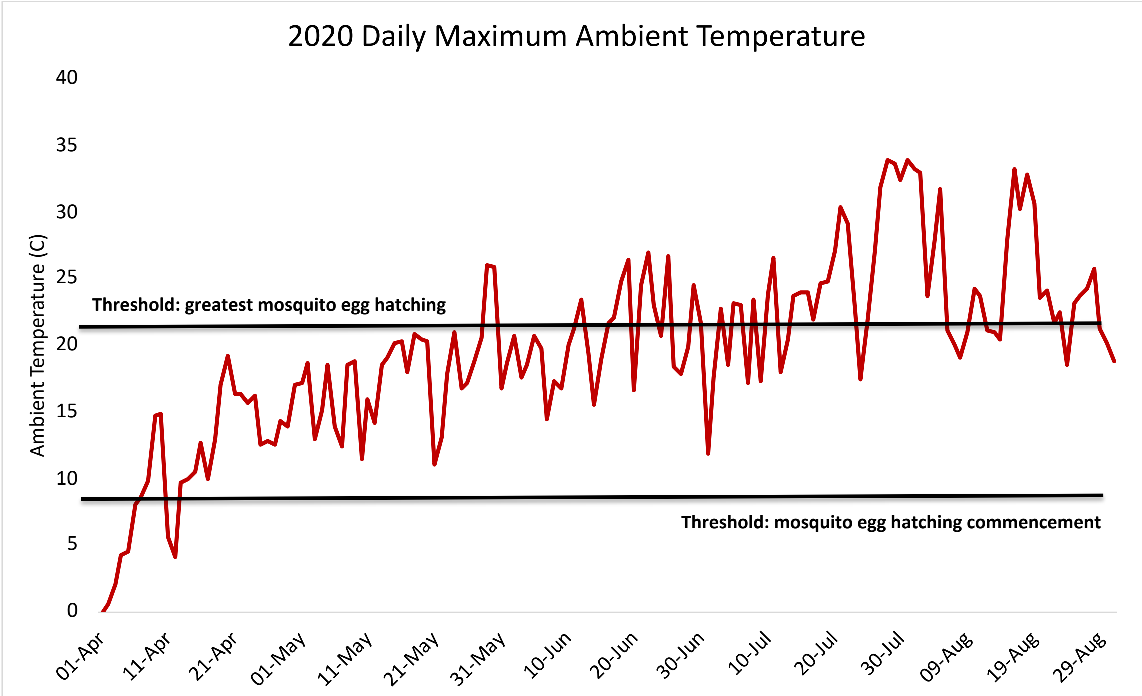

Figure 3. Maximum daily ambient temperatures (C) as recorded at the Golden Airport Station (ID: 1173220) 01 April – 31 August 2020. Lower line illustrates threshold at which *Ae. sticticus* eggs commence hatching; upper line illustrates threshold at which most *Ae. sticticus* eggs hatch.

Locally, the 2020 season also began with lower-than-normal ambient temperatures for April. However, given that mid-April temperatures were above those noted as being sufficient for mosquito egg hatching, floodwater mosquito eggs within Area ‘A’/Golden area were likely activated within April if exposed to flooding conditions (Figure 3). Floodwater eggs that were activated to hatch in mid-April would likely have hatched and developed at a considerably slow rate.

Snowmelt mosquito eggs hatch earlier than floodwater mosquito eggs. Certain snowmelt mosquito species begin to hatch at approximately 4°C water temperature and can complete development to adult emergence at 10°C (Clements 1992). Thus, snowmelt mosquito eggs laid along the Columbia River bench area were also likely triggered to hatch in April as sites began to show initial melting (Figure 3). Of note, Figure 3 shows ambient temperature, not water temperature. The delay in realized water temperature is likely a few days in relatively small, shallow sites, such as the majority of snowmelt-influenced sites found in along the mountain benches in Area ‘A’/Golden.

Local ambient temperatures in later May and into June were relatively warmer and closer to those most favourable for larval development conditions of floodwater mosquitoes (Figure 3). Accordingly, hatching and larval development rates increased significantly within those months. While ambient temperatures continued to increase from late-July through mid-August, the reduction in regional seepage sites meant that ambient temperature no longer had a direct effect on larval hatching and development due to the lack of water as a hatching cue.

Although floodwater mosquito annoyance reports reduced as August progressed, localized annoyance due to container mosquito presence may have occurred. Container mosquito habitats near residential homes can be created throughout the summer whenever water occurrence is coupled with high ambient temperatures. 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

Tracking regional river levels provides insight into mosquito egg hatching and larval development. Floodwater mosquito eggs are laid on the damp substrate of areas that experience intra-annual flooding. Within Area ‘A’/Golden, floodwater mosquito development sites primarily exist along the flooding corridor of the Columbia River (Nicholson gauge, ID: 08NA002; Donald gauge, ID: 08NB005), including associated seepage sites. The Kicking Horse River at Golden (ID: 08NB006) also contributes to the Columbia River, affecting the Donald gauge levels.

The consistent rise in regional Columbia River and Kicking Horse River levels began when a small pulse of water came through the systems in late April (Figure 4). The first measurable warming trend occurred within the Upper Columbia Basin in early May. The Columbia River at Donald exceeded 2.5 m on 20 May, after which point floodwater mosquito larval treatments typically become necessary (black line; Figure 4). It is important to note that this threshold is an approximation and may change slightly to reflect variations in interannual environmental conditions (e.g. water temperature, previous river peak:current river peak, years since comparable river peak, etc.).

Regional river levels fluctuated through mid-June with warming and cooling stints within the Upper Columbia basin. During those fluctuations, the Kicking Horse River at Golden peaked on 1 June (4.952 m). In late-June the mid-elevation snow and most of the high-elevation snowpack from the Upper Columbia Basin melted. Following suit, the Columbia River at Donald peaked on 28 June at 4.613 m and the Columbia River at Nicholson peaked on 30 June at 3.632 m (Figure 4). It is important to track all noted river levels intra-annually to best determine treatment needs. However, the Columbia River at Donald gauge provides a broader perspective for inter-annual regional freshet comparisons.

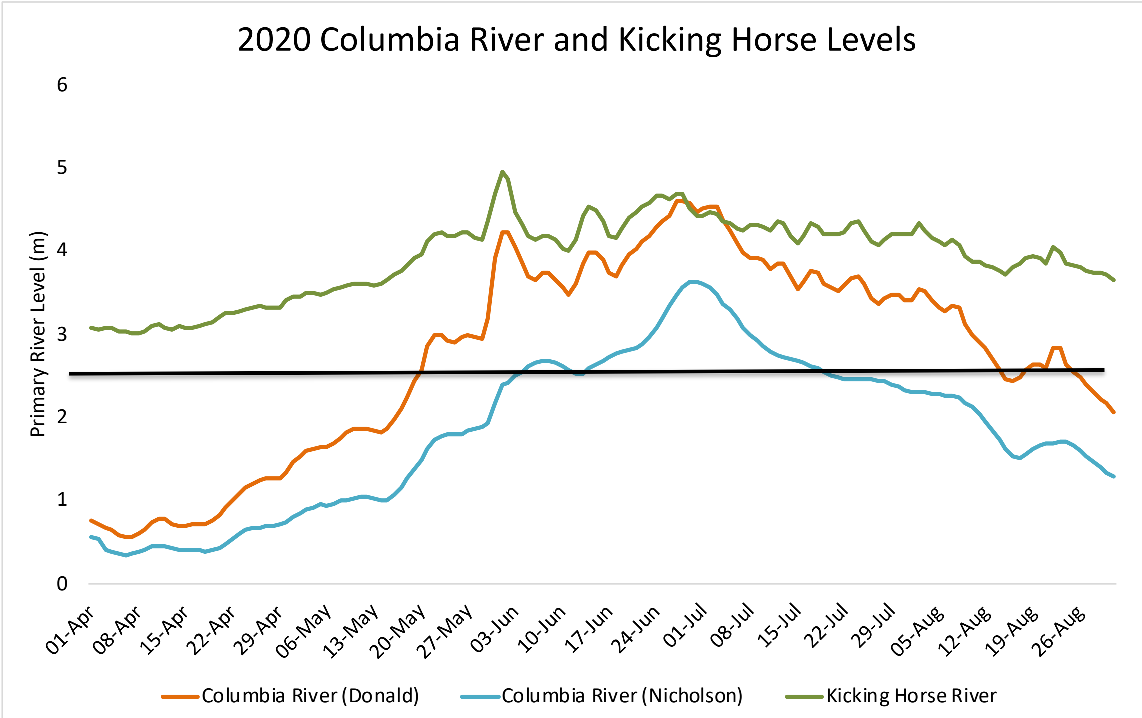

Figure 4. 2020 river levels (m) as recorded for the Columbia River (Donald gauge, 08NB005; Green) and Kicking Horse River (Golden gauge, 08NA006; Red). Horizontal black line indicates the level at which local Columbia River-associated mosquito development sites become active (2.5 m).

Regional river peaks relative to recent seasons is a predictive variable that may help explain an associated year's larval abundance. Figure 5 shows the Columbia River's levels since 2017. Although the Kicking Horse River's levels are not shown, both rivers follow the same general trend. In this way, the interannual peak trends in the Columbia River acts as representative indicators for Kicking Horse River interannual peak trends.

If the current year's regional river levels far exceed that of preceding seasons, 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 Columbia River (Donald gauge) in 2020 far exceeded those of 2019 and 2018, it is likely that the peak level noted in 2020 triggered a considerable number of eggs laid in the preceding lower-water years to hatch. As such, a higher-than-normal larval abundance was noted in the 2020 mosquito season.

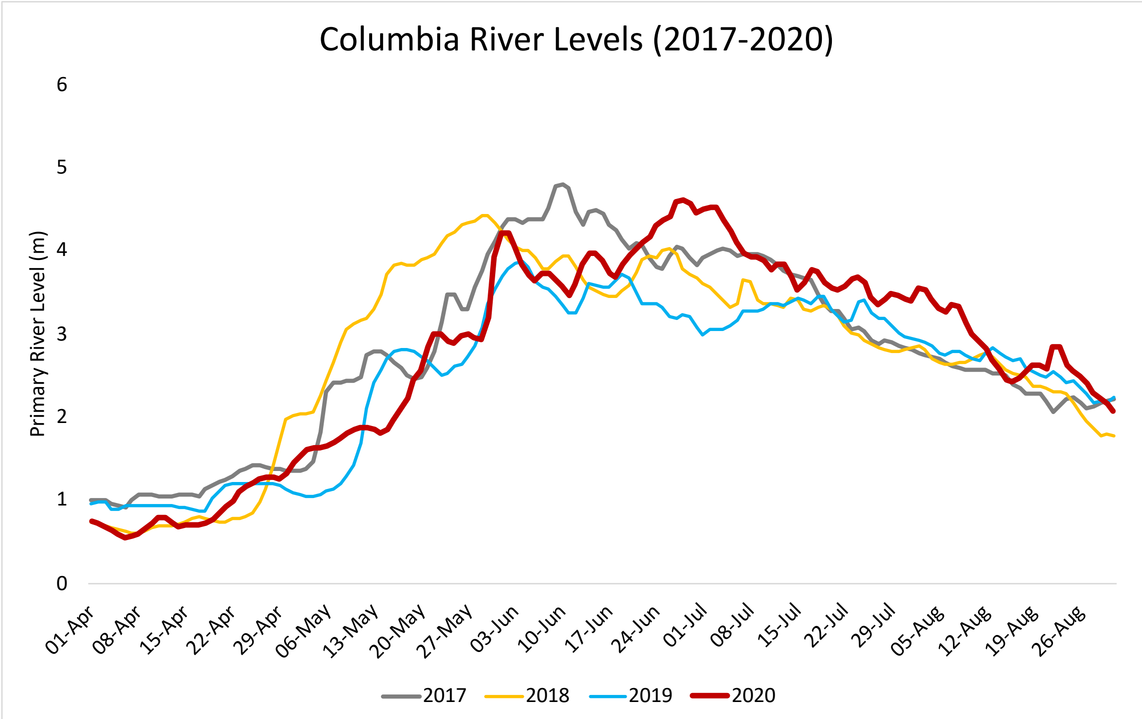

Figure 5. 2020 river levels (m) as recorded at the Columbia River (Donald gauge, 08MB005; red) with recent River levels (2017-2019), as reported by the River Forecast Centre (01 April – 31 August).

Mosquito eggs laid on substrates at various river levels have optimal environmental conditions and adequate time within which to hatch when rivers rise at a slower rate. When levels rise at high rates, mosquito eggs typically lack sufficient environmental cues to hatch due to the pulse of cold, highly oxygenated water moving through the system. The regional Columbia River and Kicking Horse River rose at moderate rates in 2020 due to the relatively slow melt of the contributing snowpack. The slow snow melt coupled with inconsistent weather meant that high Columbia River levels have also been sustained longer than normal. Thus, environmental cues were present to trigger mass mosquito hatching events at near-peak river levels.

By mid-July 2020, the Upper Columbia snow basin contributing to the Columbia River and Kicking Horse River was largely depleted of snow[8]. This depletion corresponds with a marked decline in the Columbia River by the end of July (Figures 4, 5). The Kicking Horse River continued to remain relatively high through the end of August likely due to precipitation received throughout the summer. As the Kicking Horse River is a smaller river than the Columbia River, it is more susceptible to fluctuations in local precipitation accumulation. However, by early-August many of the Area 'A'/Golden mosquito development sites associated with both regional rivers were greatly reduced or dry.

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

Larval Control

Monitoring within Area 'A/Golden began on 20 April and was primarily focused on the snowmelt mosquito development sites located on the mountain benches. Floodwater mosquito development sites associated with the Columbia River and Kicking Horse River freshets were monitored starting in early May, although treatments would not take place within floodwater sites until mid-May, closer to the timeframe in which the Columbia River at Donald approached the 2.5 m mark. Appendix I shows a map of average 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 map (Appendix I), data are 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 also 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. Of note, the areas with highest recorded larval abundance amongst known sites are near Blaeberry, Golden, and about 10 km south of Golden (Appendix I).

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 points, 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.

The first ground treatment occurred on 22 April (Figure 6). Treatments conducted in the early portion of the season (i.e. 22 April – 11 May 2019) took place at snowmelt sites northeast of Golden and just south of Blaeberry. Treatments conducted after 18 May took place at floodwater-associated sites. Floodwater treatments occurred between 18 May and 6 July (Figure 6; Table 1).

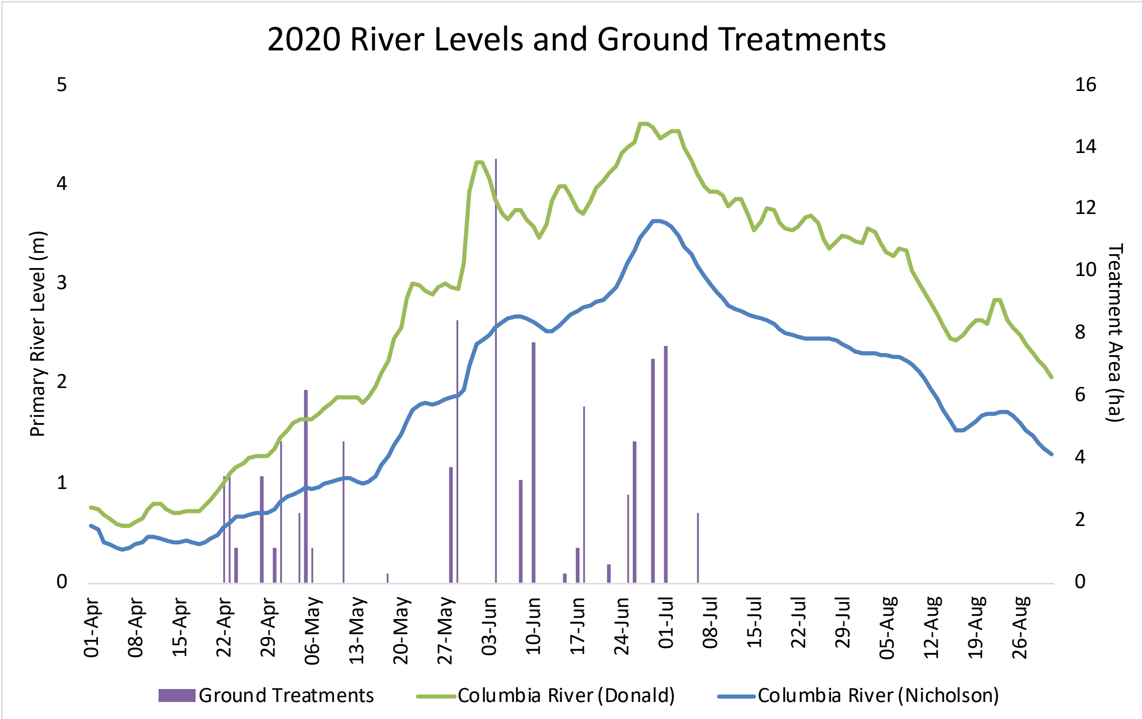

Figure 6. Columbia River levels (m; Donald gauge and Nicholson gauge) with total mosquito development area treated by ground (ha) from April 1 – August 31, 2020. Note ground treatments (ha) are recorded on the alternate y-axis.

Mosquito habitat was significantly increased in 2020 in comparison to 2019 due to high snowpack in regional basins contributing to Columbia River and Kicking Horse River levels. Both rivers peaked during a period of warming or high ambient temperatures which created ideal mosquito hatching environments. River levels started to recede in mid-July; by mid-August mosquito development areas were considerably reduced or dry. Ground treatments largely tapered-off towards the end of June. Although river levels remained high, treatments had successfully targeted the sole seasonal mosquito development events for univoltine floodwater mosquito species (Figure 6; Table 1).

Table 1. 2020 treated area (ha) by method (i.e. ground vs. aerial) and month from April - August.

	April	May	June	July	August
Ground	12.5	31.1	47.0	9.9	0.0
Aerial	0.0	182.0	1911.0	718.9	0.0
TOTAL	12.5	213.1	1958.0	728.8	0.0

Appendix II is a map depicting where and how frequently treatments took place in 2020. In certain cases, hexbins denoted as ‘Non-Detected’ or ‘Low’ do have treatments associated with them (Appendix II). In these cases, treatments may have been triggered by the larval activity of a representative site. Typically, sites 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.

Ground treatments were applied at a rate of 4 kg/ha. A total of 105 ha was treated by ground, equating to a total of approximately 402 kg of Aquabac® used (Figure 6). This treatment area total is 25 percent higher than it was in 2019 due to higher regional river levels. Typically, sites only require one treatment per season unless additional mosquito larvae are pushed into the site due to the movement of water. If additional treatments at a site are required they occur at increased water levels, hence the treatment overlap is minimal.

Aerial treatments were also applied at a rate of approximately 4 kg/ha. A total of 2,812 ha was treated by air, equating to a total of 11,248 kg of Aquabac® used (Figure 7). As with ground treatments in 2020, the total area treated by air is considerably (i.e. ~ 50 percent) higher in 2020 than in 2019 due to higher regional river levels. Five (5) aerial campaigns were required within the Area 'A'/Golden in 2020 on 8 May, 5, 11, 18, 24, and 30 June and 2 July (Figure 7). Efficacy assessments revealed >90 percent control; touch up treatments were conducted by ground around certain sites. The final aerial campaign (i.e. 30 June/2 July) was required to be conducted over 2 days due to poor weather conditions. No sites were missed in 2019. Four new sites located near the Columbia Wetlands were added in 2020. Appendix III shows more specific information about site, treatment timing, and extent of treatment.

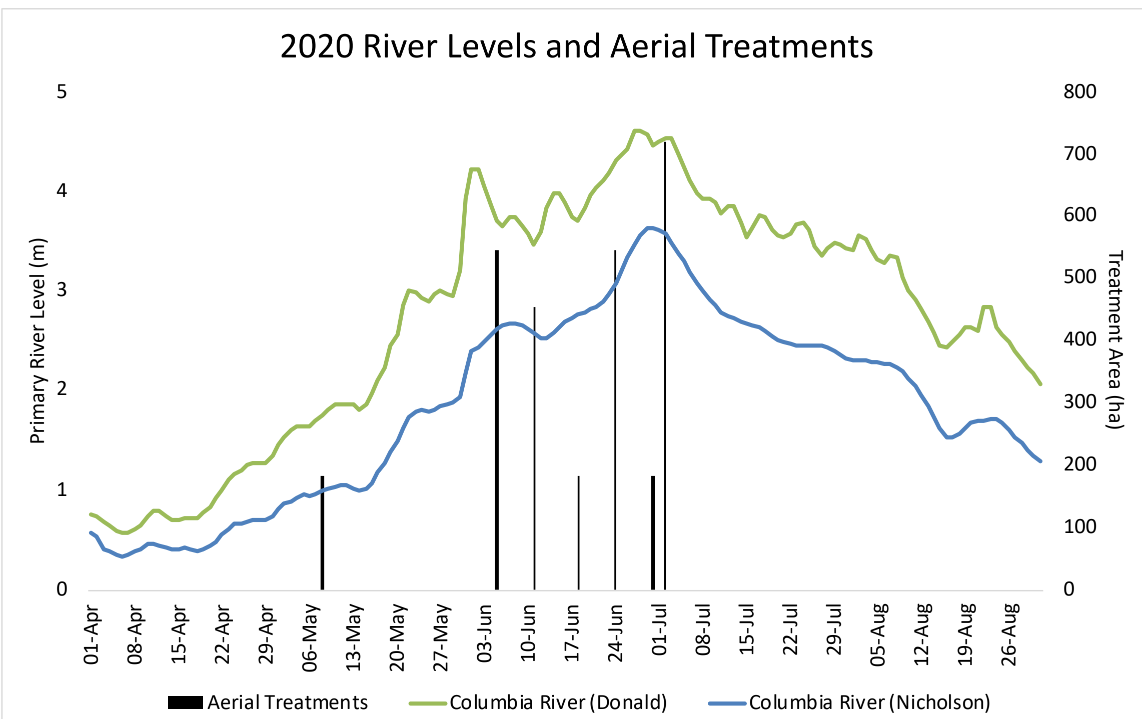

Figure 7. Columbia River levels (m; Donald gauge and Nicholson gauge) with total mosquito development area treated aerially (ha) from April 1 – August 31, 2020. Note aerial treatments (ha) are recorded on the alternate y-axis.

The total amount of area treated in 2020 is the highest since, at least, 2009 (Figure 8). While treatment area is typically directly related to peak river level, treatment area is also a function of how long the river level remains high. 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 Columbia River levels, precipitation received locally during freshet peak(s), and the primary peak occurring during high ambient temperatures.

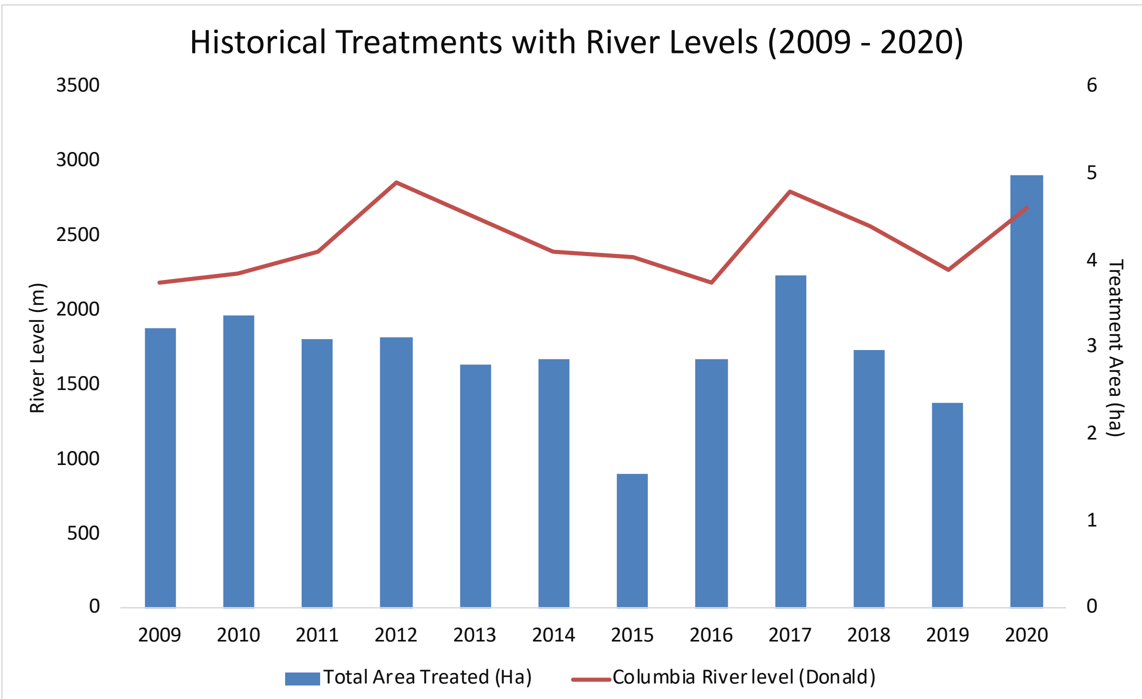

Figure 8. Columbia River levels (m; Donald gauge) with total mosquito development area treated aerially and by ground (ha) for 2009-2020. Note aerial treatments (ha) are recorded on the alternate y-axis.

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.

Phone Calls and Emails

Area 'A'/Golden residents have multiple venues to lodge calls or emails with MBL. MBL has a company-maintained hotline (877-986-3363) and email form, outlined prominently on the contact tab of the MBL website (Image 2). Additionally, residents may interact with MBL staff through social media platforms.

There was a total of seven (7) calls and zero (0) emails received in 2020. All calls and emails are designated as either concern or inquiry-based. A total of four (4) calls were designated as 'concern' and three (3) were designated as inquiry-based. Concern calls all came from the Campbell Rd, North Blaeberry, and Donald areas. Regardless of their nature, all calls and emails were returned within 24 hours. Follow-up site visits also commonly occur.

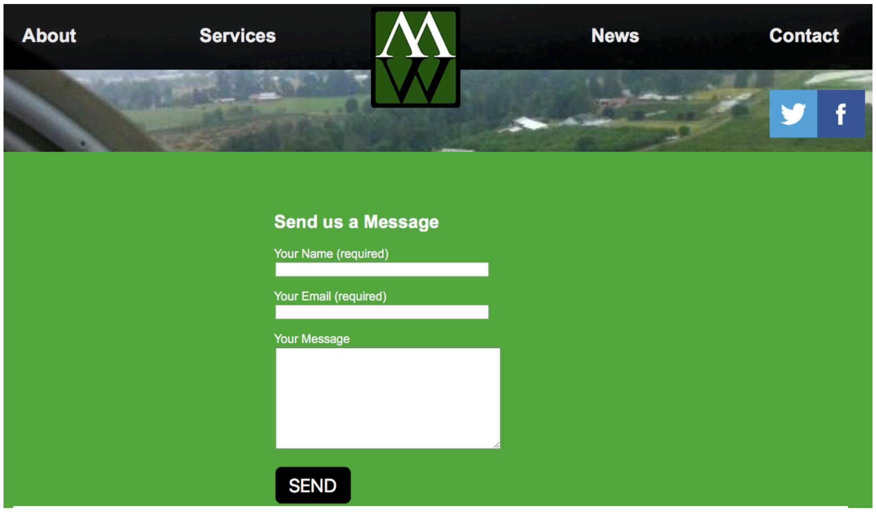

Image 2. MBL website contact form

The number of concern calls was one more than 2019, within which the lowest number of concern calls was received. Although higher than that received in 2019, the total number of concern calls is still considered low and especially for a high-water year. Through adaptive site management methods, expanding in-house site knowledge, and continued public engagement, MBL endeavours to maintain a low number of Hotline concern calls/emails.

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.

Image 3. MBL outreach pamphlet example

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 3). The pamphlet includes information about the larval control product used, mosquito biology, and personal protective tips.

Education Outreach

For the 9th year in a row, 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 2 October 2020, the MBL Facebook page was up to 326 followers, which is an increase of 20 followers since this time in 2020. This season, the highest reach for a post most relevant to the Area 'A'/Golden mosquito control program occurred on 24 June. The post described the higher-than-average mosquito annoyance as a direct result of high and sustained freshet levels, as well as cooler temperatures throughout most areas in southern BC. The post also provided personal protective tips for the longer-than-expected mosquito season this year.

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 IV) and (2) the active ingredient used in control efforts (*Bacillus thuringiensis* var. *israelensis*) (Appendix V). Additionally, a blog dedicated specifically to mosquitoes and COVID-19 was published on the MBL website (Appendix VI).

A media release was generated and approved by the CSRD program manager for distribution to radio stations with a reach within Area 'A'/Golden. On 4 June, 104.3 FM EZRock conducted an interview with MBL's head biologist. The interview included an update on general mosquito control activities occurring within the program purview. It also focused on tips to reduce mosquito breeding habitat around private properties and suggestions related to personal protective measures against mosquitoes. No additional interview requests were made in 2020.

Volunteering

MBL's company philosophy includes contributing to environmental stewardship efforts within all program purviews. MBL acknowledges that healthy ecosystems are important for a long list of reasons, including the natural suppression of mosquito abundance. As such, MBL staff are provided with volunteering opportunities each year.

In 2020, MBL staff volunteered for a total 64 hours with Wildsight Golden during stints in April and July. Ms. Eloise Sutton provided Wildsight Golden with assistance conducting bird surveys, data management, and administrative support. This is the second year that MBL staff have volunteered with Wildsight Golden and is a relationship MBL would like to continue.

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 18 May and 29 August. Within that timeframe, there were no confirmed human case of WNv reported in BC[9]. 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 4 October, there were two human cases of WNv in Washington State; both were acquired in-state within counties in the southern area of the state[10]. Additionally, 11 mosquito pools tested positive for WNv. No birds or horses/other mammals tested positive for WNv in 2020.

As of 22 September, two human WNv cases were identified in Idaho[11]. 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[12]. 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.

[9] https://www.canada.ca/en/public-health/services/diseases/west-nile-virus/surveillance-west-nile-virus/west-nile-virus-weekly-surveillance-monitoring.html
[10] http://www.doh.wa.gov/DataandStatisticalReports/DiseasesandChronicConditions/WestNileVirus
[11] https://www.cdc.gov/westnile/statsmaps/preliminarymapsdata2020/disease-cases-state-2020.html
[12] https://www.healthlinkbc.ca/health-feature/zika-virus

Program Reminders

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

- The CSRD Pest Management Plan requires updating for 2021. The process is currently being conducted by BWP Consulting Inc. in discussion with MBL.
- Notify the Ministry of Environment of the CSRD intent to treat mosquitoes in 2021 under the CSRD 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.

References

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.

Ciota, A.T., A.C. Matacchiero, A.M. Kilpatrick, L.D. Kramer. (2014). The Effect of Temperature on Life History Traits of *Culex* Mosquitoes. *J Med Entomol*. 51(**1**): 55-62.

Clements, A. (1992). *Biology of Mosquitoes.* CAB International. https://beckassets.blob.core.windows.net/product/readingsample/457488/9783540928737_excerpt_001.pdf

Horsfall, W.R. (1956). Eggs of floodwater mosquitoes III (Diptera, Culicidae). Conditioning and hatching of *Aedes Vexans*. *Ann. Entomol. Soc. Am.* 49(1): 66-71.

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.

Read, N.R. and Moon, R.D. (1996). Simulation of Development and Survival of *Aedes vexans* (Diptera: Culicidae) Larvae and Pupae. *Environ. Entomol.* 25(5): 1113-1121.

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.

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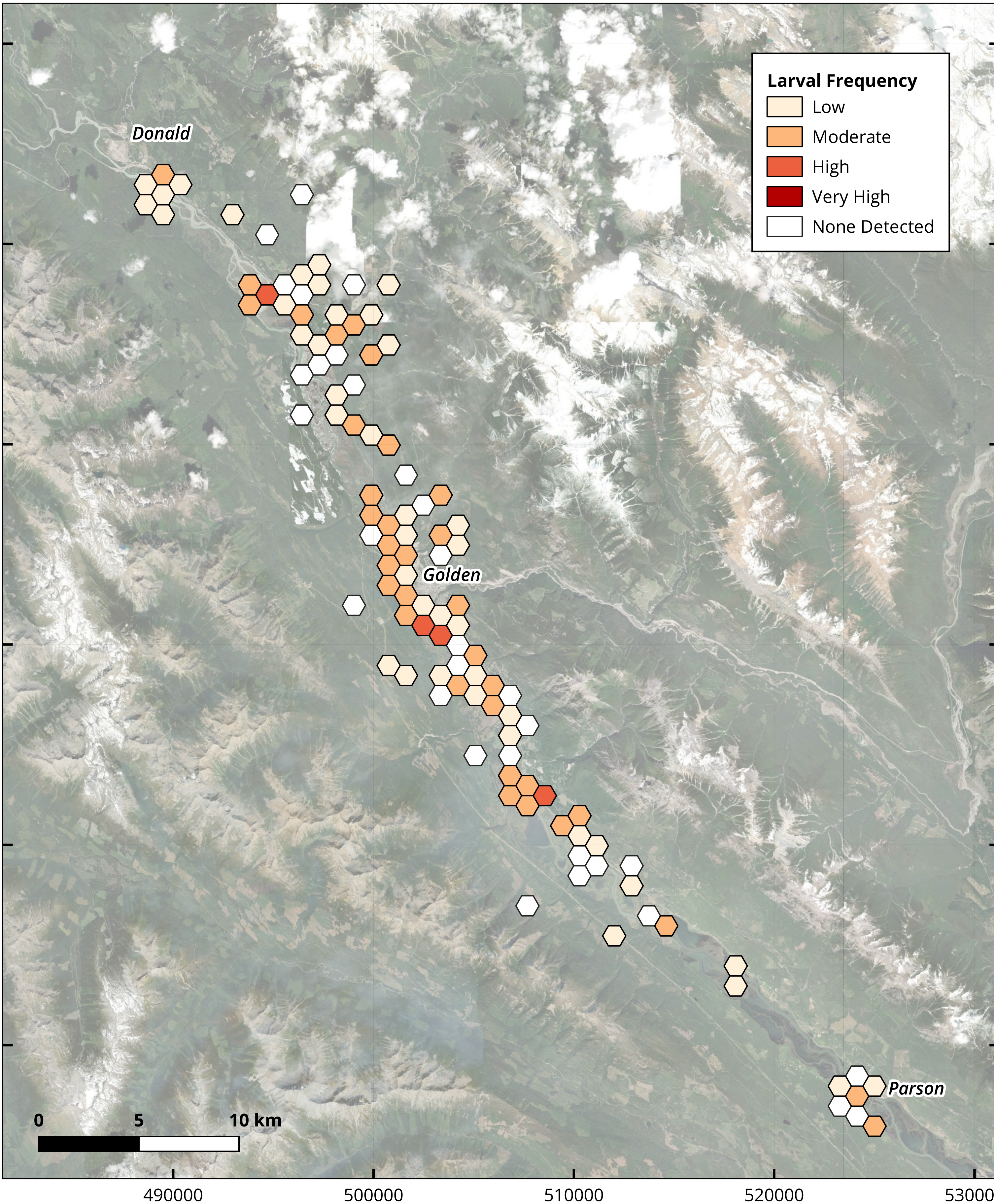
2020 Mosquito Larval Densities at Sample Locations

Appendix I-A

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

Scale = 1 : 250,000 CRS = NAD83 UTM Zone 11N



2020 Mosquito Larvicide Treatment Locations

Appendix II

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

Scale = 1 : 250,000 CRS = NAD83 UTM Zone 11N

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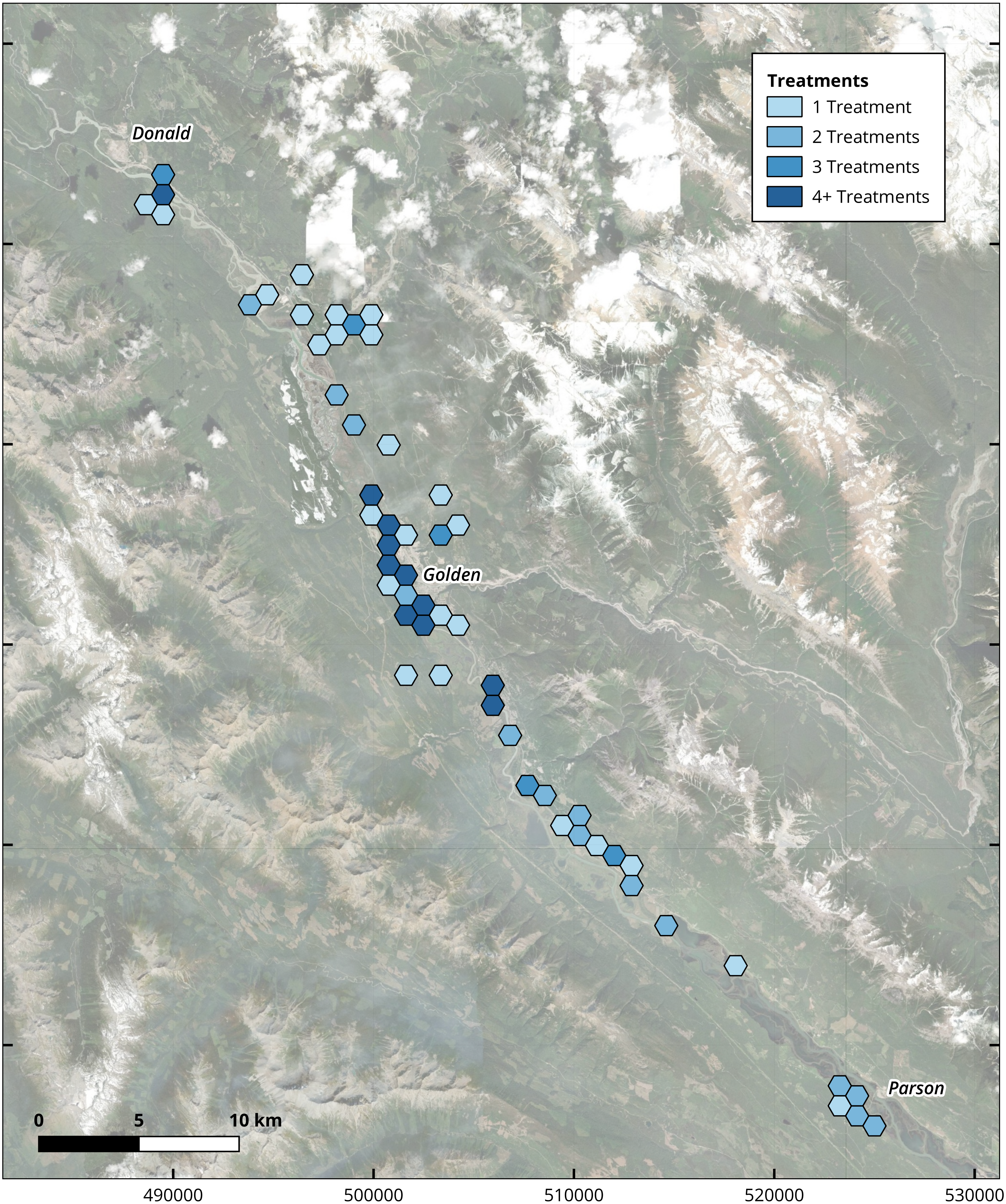


Appendix III A. 2020 ground treatment data (kg, ha) by day for Area ‘A’-Golden, BC

Site Code	Site Name	Treatment Date	Treatment Amount (Kg)	Area Treated (Ha)
CSRD-024	Highway Grey Water Pond	2020-04-22	4.55	1.14
CSRD-019	Donald Slough	2020-04-22	4.55	1.14
CSRD-095	Donald Scale Ditches	2020-04-22	4.55	1.14
CSRD-112	International Timber Frames Field	2020-04-23	4.55	1.14
CSRD-096	2601 Highway 1	2020-04-23	9.10	2.28
CSRD-089	841 Barber Road	2020-04-24	4.55	1.14
CSRD-052	Appleton Slough Lafontain Road (#2)	2020-04-28	4.55	1.14
CSRD-124	Clear Cut Stream	2020-04-28	4.55	1.14
CSRD-051	Appleton Slough Lafontain Road (#1)	2020-04-28	4.55	1.14
CSRD-105	WABS (owned by Theo residents of 2369 Upper Donald)	2020-04-30	4.55	1.14
CSRD-011	Sanders Lake Campground	2020-05-01	4.55	1.14
CSRD-094	1568 Campbell Road	2020-05-01	9.10	2.28
CSRD-125	1524 Campbell Road	2020-05-01	4.55	1.14
CSRD-043	Buffalo Ranch	2020-05-04	4.55	1.14
CSRD-092	1658 Oberg Johnson Road	2020-05-04	2.28	0.57
CSRD-090	1659 Oberg Johnson Road	2020-05-04	2.28	0.57
CSRD-124	Clear Cut Stream	2020-05-05	1.14	0.28
CSRD-093	1680 Moberly School Road	2020-05-05	13.51	3.38
CSRD-032	Al's Slough (#1) - Clair Joiner's property	2020-05-05	1.14	0.28
CSRD-034	Al's Slough (#3)	2020-05-05	1.14	0.28
CSRD-023	Wiseman Slough (#3)	2020-05-05	1.14	0.28
CSRD-022	Wiseman Slough (#2)	2020-05-05	4.55	1.14
CSRD-021	Wiseman Slough (#1)	2020-05-05	2.28	0.57
CSRD-077	1087 Upper Donald Road	2020-05-06	4.55	1.14
CSRD-055	Schiesser Road Swamp (#1)	2020-05-11	9.10	2.28
CSRD-060	1810 Schiesser Road	2020-05-11	9.10	2.28
CSRD-048	Cedar Lake (South End)	2020-05-18	1.14	0.28
CSRD-004	LP swamp	2020-05-28	13.65	3.41
CSRD-107	Kicking Horse Seepage	2020-05-28	1.14	0.28
CSRD-085		2020-05-29	6.06	1.52
		2020-05-29	6.06	1.52
CSRD-061		2020-05-29	1.14	0.28
CSRD-005	Golf Course (#1)	2020-05-29	4.55	1.14
CSRD-003	Swamp Behind Old Mill	2020-05-29	1.14	0.28
CSRD-063	Columbia Wetlands Golden	2020-05-29	1.14	0.28
CSRD-046	Nicholson Wetlands	2020-05-29	9.10	2.28
CSRD-065	Confluence Park	2020-05-29	4.55	1.14
CSRD-084	Watson Farm	2020-06-04	9.10	2.28
CSRD-139	Benson farm	2020-06-04	9.10	2.28
CSRD-045	Eco Adventure Ranch	2020-06-04	4.55	1.14
CSRD-031	Nicholson Boat Launch	2020-06-04	13.65	3.41
CSRD-003	Swamp Behind Old Mill	2020-06-04	4.55	1.14
CSRD-064	Airport Runway	2020-06-04	4.55	1.14
MA-008	Railway ditch	2020-06-04	2.28	0.57
CSRD-075	Rotary Trails	2020-06-04	2.28	0.57
CSRD-107	Kicking Horse Seepage	2020-06-04	4.55	1.14
CSRD-025	Cooper Alfred Road Wetlands	2020-06-08	1.13	0.28
CSRD-084	Watson Farm	2020-06-08	3.03	0.76
CSRD-076	15th Street Swamp forest	2020-06-08	2.28	0.57
CSRD-074	Airport South End	2020-06-08	2.28	0.57
CSRD-005	Golf Course (#1)	2020-06-08	4.55	1.14
	Cow fields	2020-06-10	11.00	2.75
CSRD-010	Race Track	2020-06-10	1.82	0.46
CSRD-045	Eco Adventure Ranch	2020-06-10	4.55	1.14
CSRD-003	Swamp Behind Old Mill	2020-06-10	9.10	2.28
CSRD-031	Nicholson Boat Launch	2020-06-10	4.55	1.14
CSRD-139	Benson farm	2020-06-15	1.14	0.28
CSRD-003	Old Mill	2020-06-17	1.14	0.28
CSRD-107	Kicking Horse Seepage	2020-06-17	1.14	0.28
CSRD-075	Rotary Trails	2020-06-17	1.14	0.28
CSRD-076	15th Street Swamp forest	2020-06-17	1.14	0.28
CSRD-110	Parson Wetlands West #2,3806 Thomas Road	2020-06-18	2.28	0.57
CSRD-111	Parson Wetland West #3, 3776 Sanborn Road	2020-06-18	6.83	1.71
CSRD-028	Parson RV Park	2020-06-18	13.65	3.41
CSRD-084	Watson Farm	2020-06-22	2.28	0.57
CSRD-064	Airport Runway	2020-06-25	2.28	0.57
	Airport ditch	2020-06-25	4.55	1.14
CSRD-075	Rotary Trails	2020-06-25	4.55	1.14
CSRD-045	Eco Adventure Ranch	2020-06-26	13.65	3.41
CSRD-076	15th Street Swamp forest	2020-06-26	4.55	1.14
CSRD-139	Benson farm	2020-06-29	10.62	2.65
CSRD-005	Golf Course (#1)	2020-06-29	4.55	1.14
CSRD-138	CP ditch	2020-06-29	13.65	3.41
	Airport ditch	2020-07-01	4.55	1.14
CSRD-084	Watson Farm	2020-07-01	12.20	3.05
CSRD-075	Rotary Trails	2020-07-01	13.65	3.41
CSRD-010	Race Track	2020-07-06	4.55	1.14
CSRD-104	Columbia Wetland Adventures	2020-07-06	4.55	1.14

Appendix III B. 2020 aerial treatment data (kg, ha) by day for Area ‘A’-Golden, BC

Areas Treated	Treatment Date	Treatment Amount (Kg)	Area Treated (Ha)
15th Street Swamp forest,Columbia Wetlands North (#1),Golf Course (#1),Airport Runway,Old Mill,Horse Creek Wetlands (south end),Horse Creek North ,Parson Wetlands West #1, 3950 Thomas Road,Mitchell Road wetlands,Columbia Wetlands South (#6),Parson Wetland West #3, 3776 Sanborn Road,Parson Wetlands West #2,3806 Thomas Road,Watson Farm,Parson RV Park,Nicholson Boat Launch,Habart Wetlands	2020-07-02	2875.60	718.90
Horse Creek Wetlands (south end),Nicholson Wetlands,Eco Adventure Ranch,Golf Course (#1)	2020-06-30	728.00	182.00
Confluence Park,Columbia Wetlands North (#1),Low Lying Forest 2,Old farm (highway 1),Old Mill,Nicholson Boat Launch,Habart Wetlands,Nicholson Wetlands,Sandhill Lake (east shore),Parson Wetlands West #1, 3950 Thomas Road,Parson Wetlands West #2,3806 Thomas Road,Parson Wetland West #3, 3776 Sanborn Road	2020-06-24	2184.00	546.00
Nicholson Boat Launch,Nicholson Wetlands,Sandhill Lake (east shore)	2020-06-18	728.00	182.00
Golf Course (#1),LP swamp,Columbia Wetlands North (#1),Sandhill Lake (east shore),Nicholson Wetlands,Columbia Wetlands South (#6),Horse Creek North ,Horse Creek Wetlands (south end),Habart Wetlands,Nicholson Boat Launch,Old Mill	2020-06-11	1820.00	455.00
Golf Course (#1),Low Lying Forest 2,Old farm (highway 1),LP swamp,Confluence Park,Columbia Wetlands Golden,Sandhill Lake (east shore),Eagle Pete's Wetland,Habart Wetlands,Nicholson Wetlands,Nicholson Boat Launch,Columbia Wetlands South (#6),Horse Creek North ,Wetland Strip,Mitchell Road wetlands,Parson RV Park	2020-06-05	2184.00	546.00
The Ford Roade Station Nightmare,Highway 1 Wetland,Cooper Lake,Columbia Wetlands North (#3),Reflection Lake (North),Reflection Lake (South),Nicholson Wetlands,Hidden swamp,Palumbo Heights Swamp,1816 Campbell Road,Mirage swamp,2045 Mitchell Rd.	2020-05-08	728.00	182.00

Frequently Asked Questions

Floodwater Mosquito Biology and Disease Transmission

MorrowBioScience Ltd.

Updated: 3 May 2020

Updated: 3 May 2020

Table of Contents

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.*

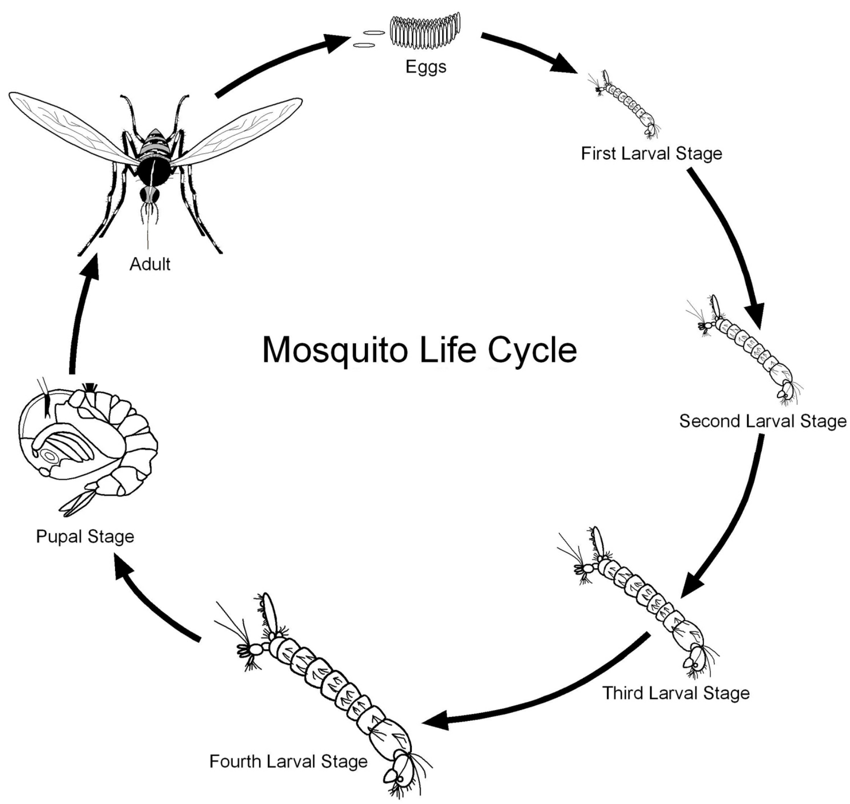
Significant local precipitation accumulation may also elevate local river levels. Local precipitation can temporarily increase seepage site levels, where mosquito development habitat is located. Thus, tracking local precipitation accumulation can aid MBL field staff with determining how long mosquito 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*

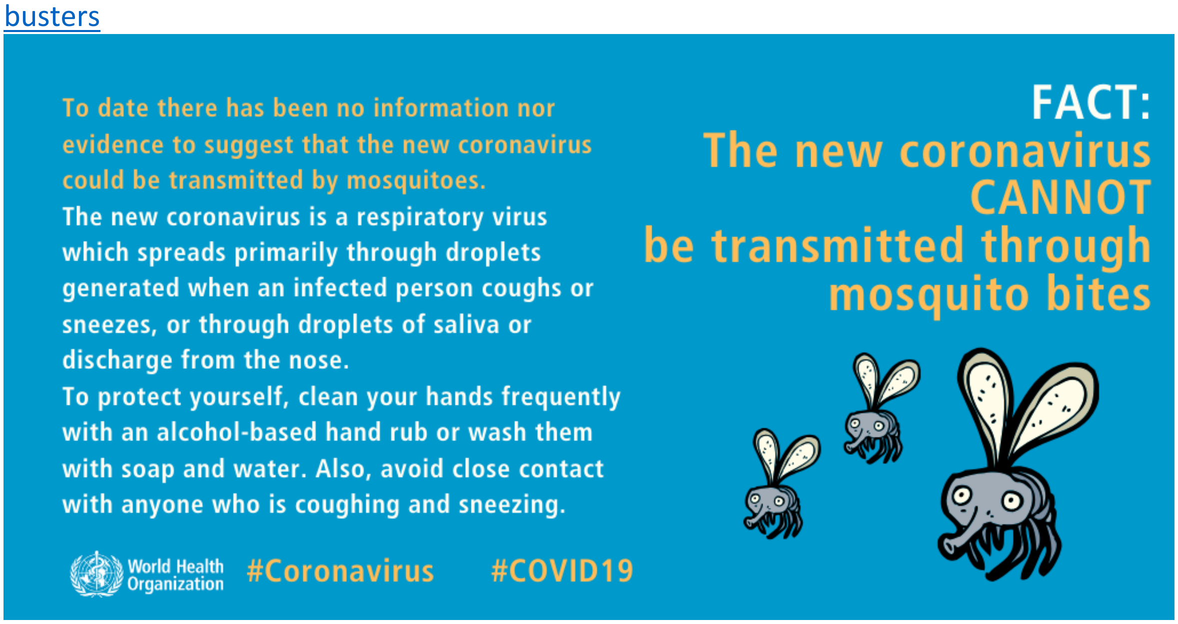
The BC Centre for Disease Control (BCCDC) website also contains health-related information for residents. The BCCDC site has a more detailed map of surveillance activity by region. It can be found at: http://www.bccdc.ca/health-info/diseases-conditions/west-nile-virus-wnv

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
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.

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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.

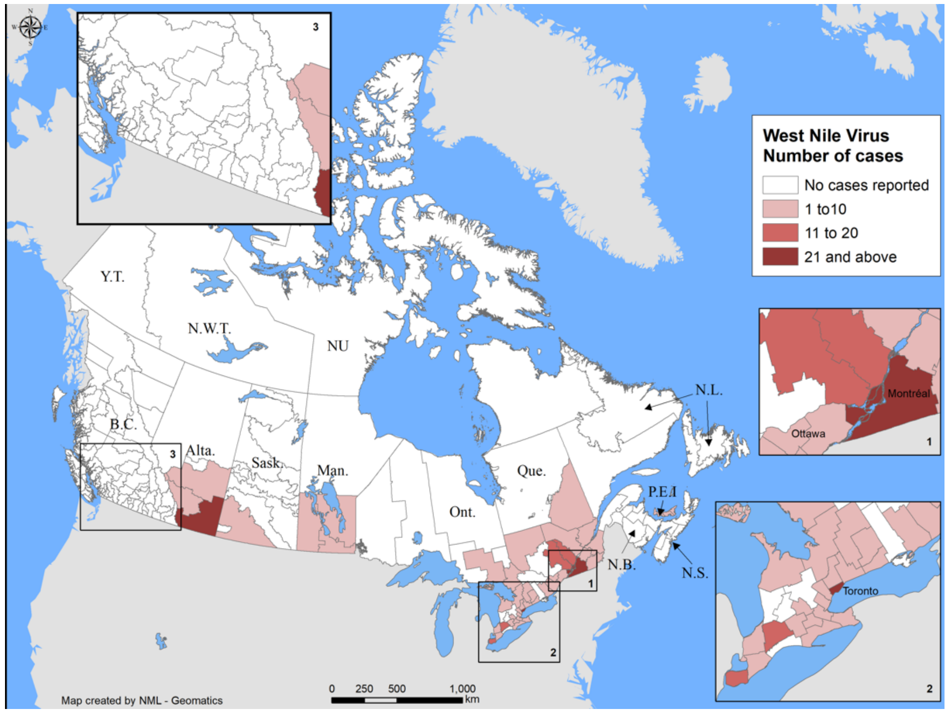

Image 2. 2018 distribution of human West Nile virus cases throughouth Canada (Health Canada)

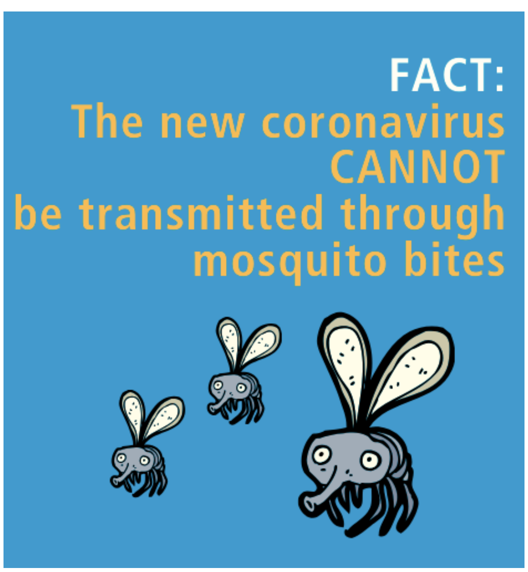

Image 3. World Health Organization myth busters

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.