REGIONAL DISTRICT OF EAST KOOTENAY
WASA, TA TA CREEK, SKOOKUMCHUCK
MOSQUITO CONTROL PROGRAM
2020 YEAR-END REPORT

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Executive Summary

Morrow BioScience Ltd. (MBL) has now completed the 24th consecutive year as mosquito control contractor for Wasa/Ta Ta Creek/Skookumchuck within the Regional District of East Kootenay (RDEK). This season, 2020, concludes the 4^{th} year of a 5-year contract. Floodwater mosquito development site knowledge for this specific program is broad and detailed. The primary goal for the mosquito control program is to reduce floodwater mosquito abundance within Wasa/Ta Ta Creek/Skookumchuck. Most control activity takes place along the Kootenay River and at associated seepage sites.

Snowpack conditions in the East Kootenay Basin were higher than normal leading into the 2020 floodwater mosquito season. A regional warming trend in early May within the contributing snow basin led to the start of the mosquito season. A secondary warming stint in late May triggered the melting of the majority of regional snowpack and led to the peak in the local Kootenay River. The Kootenay River at Fort Steele peaked on 1 June at 4.45 m. Significant precipitation was locally received in May and June, augmenting river levels, seepage sites, and micro-sites. A high abundance of floodwater mosquito eggs - compounded from previous seasons - hatched in 2020. Large-scale, concurrent hatching events resulted in an increased need for treatments, including two aerial treatment days. No known sites were missed in 2020, however the inability to treat the extensive floodwater mosquito habitat in Bummer's Wetland caused widespread adult mosquito emergence and associated nuisance issues throughout the program area. Three concern calls and emails, each, were received in 2020. All were promptly responded to. No human-cases of West Nile virus or Zika virus were reported by the BC CDC in 2020.

Between 21 May and 30 June, a total of 1,305 hectares were treated by ground in 2020. This total is greater than five times the area treated in 2019. Ground and aerial treatment efficacy was assessed as high. Liquid Aquabac® was used in conjunction with granular Aquabac®, with highly efficacious results. A real-time monitoring and treatment data dashboard was provided to the RDEK program manager. The dashboard enabled the manager to view up-to-date treatment information and ensure quality control.

Communications with program 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 additional information pamphlets and blogs available through the MBL website (www.morrowbioscience.com) and also directly from the RDEK program manager. MBL staff provided a total of two (2) interviews to provincial television news outlets and one (1) local interview to 102.9 FM 'The Drive' radio hosts on 5 June. 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 RDEK are aware of mosquito abatement efforts.

Season Highlights

- The average snowpack in the East Kootenay Basin was 113 percent of normal in April, immediately preceding the onset of the mosquito season.
- A region-wide warming event within the East Kootenay Basin prompted considerable low and mid-elevation snow melt conditions in early May.
- A late-May warming trend across the province prompted the majority of contributing snowpack to melt.
- The snowpack in the contributing basin was depleted by the end of June.
- Variable weather in the 2020 mosquito season resulted in multiple peaks to the regional Kootenay River.
- The peak Kootenay River level at the Fort Steele gauge occurred on 1 June at 4.45 m.
- The peak was the highest since, at least, 2013.
- Ground treatments started on 21 May and concluded on 30 June.
- A total of 419 ha was treated by ground (1,674 kg granular Aquabac®).
- Two aerial treatment days were conducted: 7 and 10 June.
- A total of 887 ha was treated aerially (2,621 kg granular Aquabac®; 450,000 ml liquid Aquabac®).
- Liquid Aquabac® was used for the first time in 2020, revealing high efficacy and requiring reduced storage requirements.
- Four (4) Mosquito Hotline calls were received in 2020, three (3) of which were designated as ‘concern’.
- Three (3) concern emails were received in 2020.
- The relatively high number of concern calls and emails is reflective of a high-water year, the Kootenay River peak occurring during high ambient temperatures, and the inability to treat Bummer’s Wetland.
- MBL staff provided interviews to 102.9 FM ‘The Drive’ radio (5 June), CTV (July 3) and Global News (July 10).
- MBL’s real-time data management and mapping portal provided RDEK program managers with improved ability to target areas and gave quality control assurance for clients.

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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 providers for the Wasa/Ta Ta Creek/Skookumchuck within the Regional District of East Kootenay (RDEK) since 1997. In 2017, MBL started a renewed five (5) year contract; this season – 2020 – is the fourth of the contract.

This area of the RDEK involves dynamic floodwater mosquito habitat and considerable program reach during high-water years. These variables make the Wasa/Ta Ta Creek/Skookumchuck mosquito control program complex. Historical experience with this program and other comparable regional programs has created a strong knowledge base from which to build. That understanding has helped improve floodwater mosquito development site management within this mosquito control program. In addition to MBL's knowledge base, MBL's commitment to public engagement, program data transparency through the use of MBL's in-house real-time data collection portal and client dashboard, and improved environmental accountability via annual carbon offset purchases further strengthens the Wasa/Ta Ta Creek/Skookumchuck program. MBL's goal is to continue to provide effective floodwater mosquito control to program residents while remaining socially and environmentally responsible.

Carbon Offsets

The spatial reach of the Wasa/Ta Ta Creek/Skookumchuc mosquito program is such that driving is an inevitable requirement. The accumulated mileage over the course of 2020 was approximately 14,392 km (ground transportation only).

As an estimation, the driving requirements for this program result in the production of approximately 5 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 RDEK.

Methodology

The primary targets of the Wasa/Ta Ta Creek/Skookumchuck 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 Wasa/Ta Ta Creek/Skookumchuck, floodwater mosquito development sites primarily exist along the flooding corridor of the Kootenay River, including associated seepage sites. When water floods these sites, due to the freshet and/or significant localized

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

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 compound number of mosquito eggs to hatch, resulting in 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.

MBL field technicians begin monitoring all known mosquito development sites within Wasa/Ta Ta Creek/Skookumchuck prior to the Kootenay River levels rising in the spring (Image 1). 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 potential accelerated mosquito development rates with rising temperatures (Read and Moon 1996). Hence, as regional river levels and local ambient temperatures begin to rise consistently, monitoring efforts increase accordingly.

Image 1. Standard 350 ml dip collected from mosquito development site showing 2nd and 3rd instar mosquito larvae.

Larval mosquitoes in sufficient number (i.e. >4/dip; Image 1) are treated by ground applications of a microbial larvicide product, 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 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. 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 are flooded, it becomes increasingly difficult to treat sites in a timely manner by ground due to access challenges 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 multiple days to complete aerial treatment campaigns, depending on weather conditions.

Treatments are timed according to the instar stage of larval development, targeting the 3^{rd} and 4^{th} instars. 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 3^{rd} and early 4^{th} instar stages, early instar larvae are available as food sources in their ecosystem.

Sites are treated when a standard dip (350ml) collects >4 late instar (3^{rd} or 4^{th} instar) larvae per dip. When flooding commences and ambient temperatures rise, many dips easily exceed this threshold. Larval densities within the range of 200-500 per dip are commonly detected (Image 1). All sites are checked within one or two 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 the Kootenay River levels throughout the mosquito season (i.e., April – July) are: 1) the snowpack in basins contributing to the Kootenay River, 2) ambient temperature in snow basins contributing to the Kootenay River, and 3) local precipitation. Local ambient temperature is also of interest due to the effect local ambient temperature can have on mosquito egg hatching and larval development rates. As such, all noted conditions are tracked throughout the season.

Snowpack

Floodwater mosquito abundance within the Wasa/Ta Ta Creek/Skookumchuck area is primarily governed by regional Kootenay River water levels (Fort Steele gauge – ID: 08NG065). In turn, the water levels of that system are mainly governed by the freshet released from the East Kootenay Basin. Frequent and large amounts of local precipitation can also affect river levels. However, in normal years, localized precipitation accumulation typically affects river levels to a lesser degree than the Basin – associated freshet during the late spring and early summer.

There are eight snow stations within the East Kootenay basin, with three of those stations depicting real-time snowpack trends throughout the year (Image 2). Basin averages are

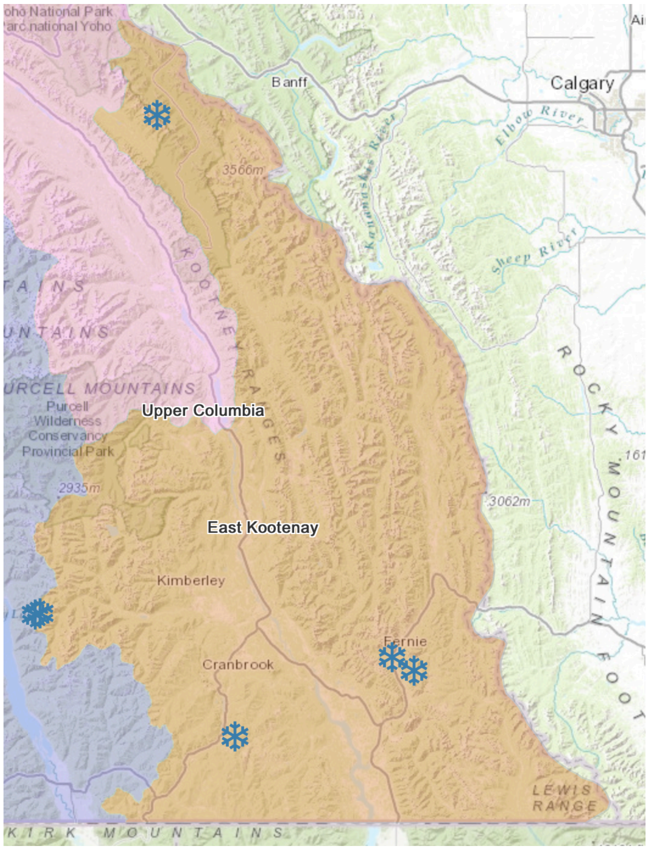

Image 2. East Kootenay basin, showing three real-time snow stations (i.e., snowflakes).

reported throughout the season in Provincial Water Supply Bulletins[2]. In April immediately preceding the commencement of the larval mosquito monitoring season, the snowpack within the East Kootenay Basin was 113 percent of normal[3]. While only weak systems were recorded in April, ambient temperatures within Southern British Columbia were cooler-than-normal. The snowpack in this basin increased through much of April[4].

The Automated Snow Weather Station at Morrissey Ridge (ID: 2C09Q) is one of the closest snow stations to Wasa/Ta Ta Creek/Skookumchuck (Figure 1) within the East Kootenay Basin. It serves as a representative station for middle-elevation snowmelt within the East Kootenay Basin. The first measurable melting trend occurred in early May, with the lower and some middle-elevation snowpack data showing drops in Snow Water Equivalent (SWE; Figure 1). Unstable weather systems occurring in mid-May also brought cooler weather at various points, augmenting snowpack in some northern areas of the East Kootenay Basin (Image 2). A more intense warming event occurred at the end of May[5]. This warming trend resulted in the melting of most of the middle-elevation and some high-elevation snowpack, as depicted at the Morrissey Ridge snow station (Figure 1). This warming trend also led to the official peak of the regional Kootenay River (see 'River Levels' below).

[2] https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/drought-flooding-dikes-dams/river-forecast-centre/snow-survey-water-supply-bulletin
[3] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/river-forecast/2020_apr1.pdf
[4] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/river-forecast/2020_may1.pdf
[5] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/river-forecast/2020_june1.pdf

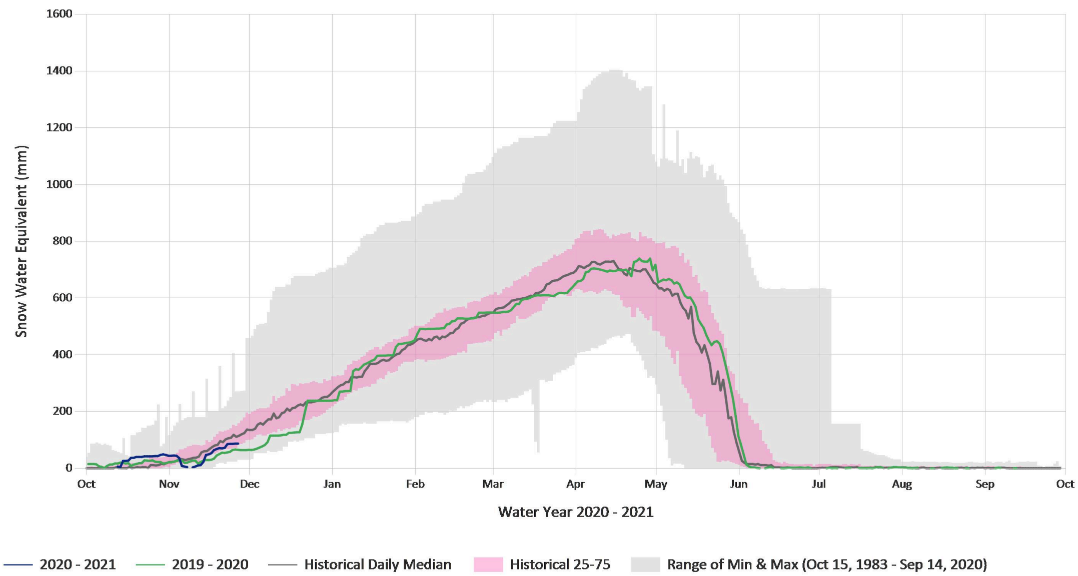

Figure 1. Automated Snow Weather Station data from Morrissey Ridge (ID: 2C09Q). Green line represents data from 2019-2020.

Despite warming weather in the East Kootenay Basin, there was still some remaining snow at the Floe Lake snow station (ID: 2C14P), a higher elevation snow station in the northern area of the Basin. The Floe Lake station is likely representative of other regional high elevation stations contributing snowmelt to the Kootenay River. A warming trend in early June initiated the final pulse of snowmelt in the higher elevation areas of the Basin. However, the snowmelt was gradual, resulting in continuous input to the regional Kootenay River through June. The variable melting, cooling, and augmenting of the regional snowpack in June led to lower, secondary and tertiary peaks in the regional Kootenay River (see 'River Levels' below). By the end of June, all high-elevation snow had been depleted (Figure 2).

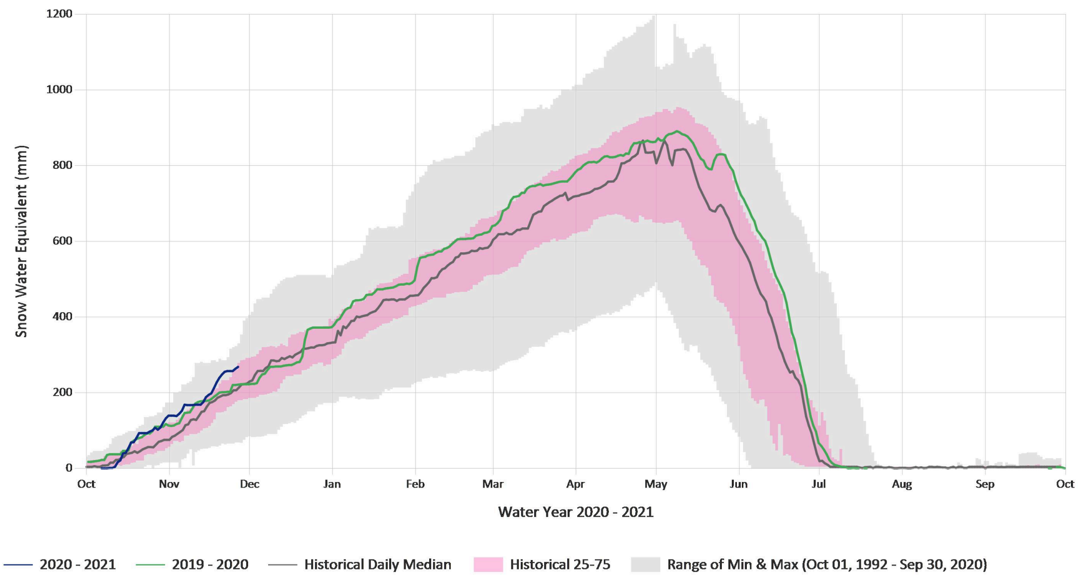

Figure 2. Automated Snow Weather Station data from Floe Lake (ID: 2C14P). Green line represents data from 2019-2020.

Local Precipitation

Significant temporally and spatially concentrated precipitation accumulation may elevate regional Kootenay River levels. Local precipitation can also temporarily increase seepage site levels and create micro-mosquito development sites, such as hoof prints and car tracks. The Cranbrook Airport Auto weather station is the closest weather station to the Wasa/Ta Ta Creek/Skookumchuck area (Climate ID: 1152106). Tracking local precipitation accumulation allows for some level of prediction regarding larval mosquito development rate and treatment timing requirements.

The precipitation received at the Cranbrook Airport Auto weather station during the 2020 mosquito season ranged from below average to considerably greater-than-average (Figure 3). Precipitation received in April was low and approximately 10 mm lower than the station average (i.e., 1981-2010). It is likely that precipitation did not augment local river levels and associated mosquito development sites in April.

However, May precipitation accumulation in 2020 exceeded the station average by approximately 40 mm (Figure 3). The majority of precipitation received in May occurred in the middle and at the end of the month. Thus, local precipitation received in May was on top of the rising freshet and near the regional Kootenay River peak date (see 'River Levels' section below). The timing and amount of precipitation received in May augmented regional mosquito development sites.

Precipitation received to the area in June was also higher than the station average (Figure 3; 40.8 mm). However, the majority of precipitation received in June occurred toward the end of the month, as regional Kootenay River levels were declining. While it is unlikely that precipitation received in June measurably augmented regional Kootenay River levels, it is likely that precipitation received at the end of the month created or impacted current micro-mosquito development sites.

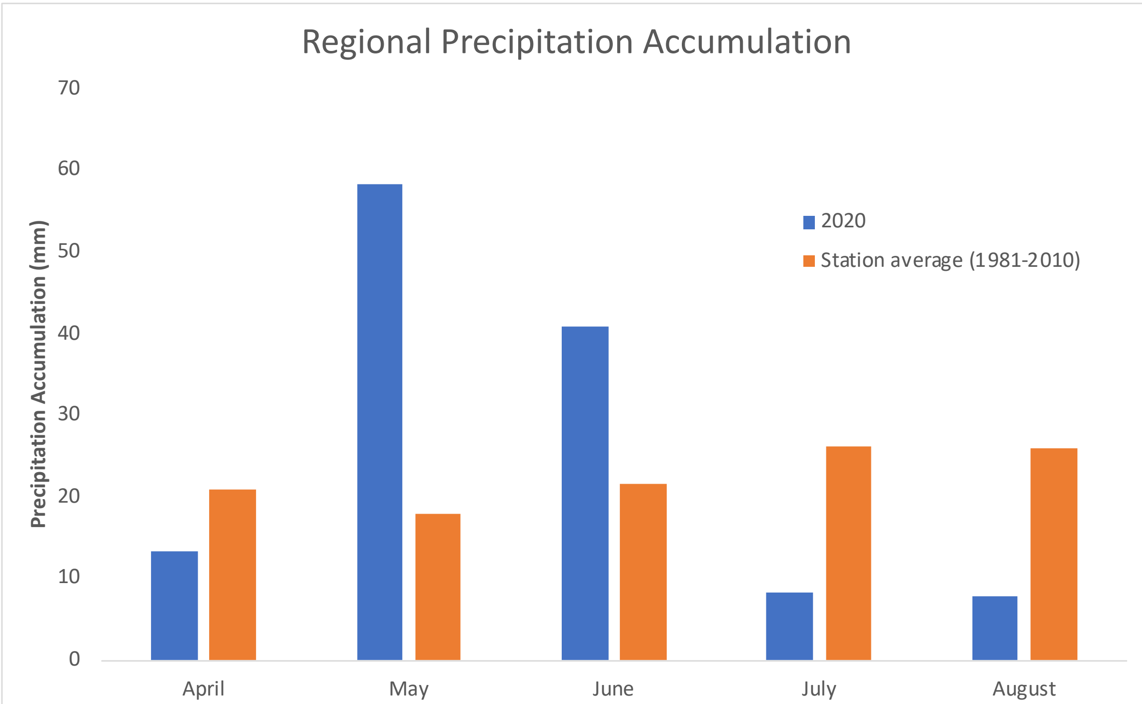

Figure 3. Precipitation values (rainfall and snow accumulation; mm) recorded at the Cranbrook Airport Auto weather station (Climate ID: 1152106) for 01 April – 31 August 2020 (blue) and average station precipitation values (1981-2010; orange).

Precipitation received to the area in July and August was notably low (Figure 3). Given that regional Kootenay River levels and associated seepage sites were low by that point in the season, it is unlikely that late-season precipitation created additional floodwater mosquito habitat. However, the small amount of precipitation received in these months would have been sufficient to activate container mosquito eggs to hatch. Thus, it's possible that adult mosquito presence toward the end of the season was likely due to container mosquito hatches, not floodwater species.

Ambient Temperature

From April through August, ambient temperature fluctuations both within the contributing snow basin and locally, can affect mosquito egg hatching, larval development rates, and adult dispersal rates. The 2020 mosquito season began in April with below-normal ambient temperatures across most of the East Kootenay Basin. The 1 May Snow Survey and Water Supply Bulletin[6] reported below-average ambient temperatures within the East Kootenay Basin through April. The cooler weather resulted in a 2-week delay of the regional Kootenay River freshet. Brief periods of warming temperatures melted low-elevation snow in the East Kootenay basin and contributed relatively little to the regional Kootenay River in April.

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

High pressure trends within the East Kootenay basin in early and late-May aided in the increased melting rate of the majority of the mid and high-elevation snowpack. The increase in ambient temperatures in late May ultimately led to the regional Kootenay River peak in 2020 (see 'River Levels' below). Temperature data is consistent with 2020 automated snow station data[7] depicting snowmelt points correlating with regional ambient temperature spikes.

Immediately after the majority of the freshet has come out, local ambient temperatures become more indicative of floodwater mosquito egg hatching and larval development. If the ground proximate to the Kootenay 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 survival was low and 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 Wasa/Ta Ta Creek/Skookumchuck it serves as a representative species for our purposes and provide 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

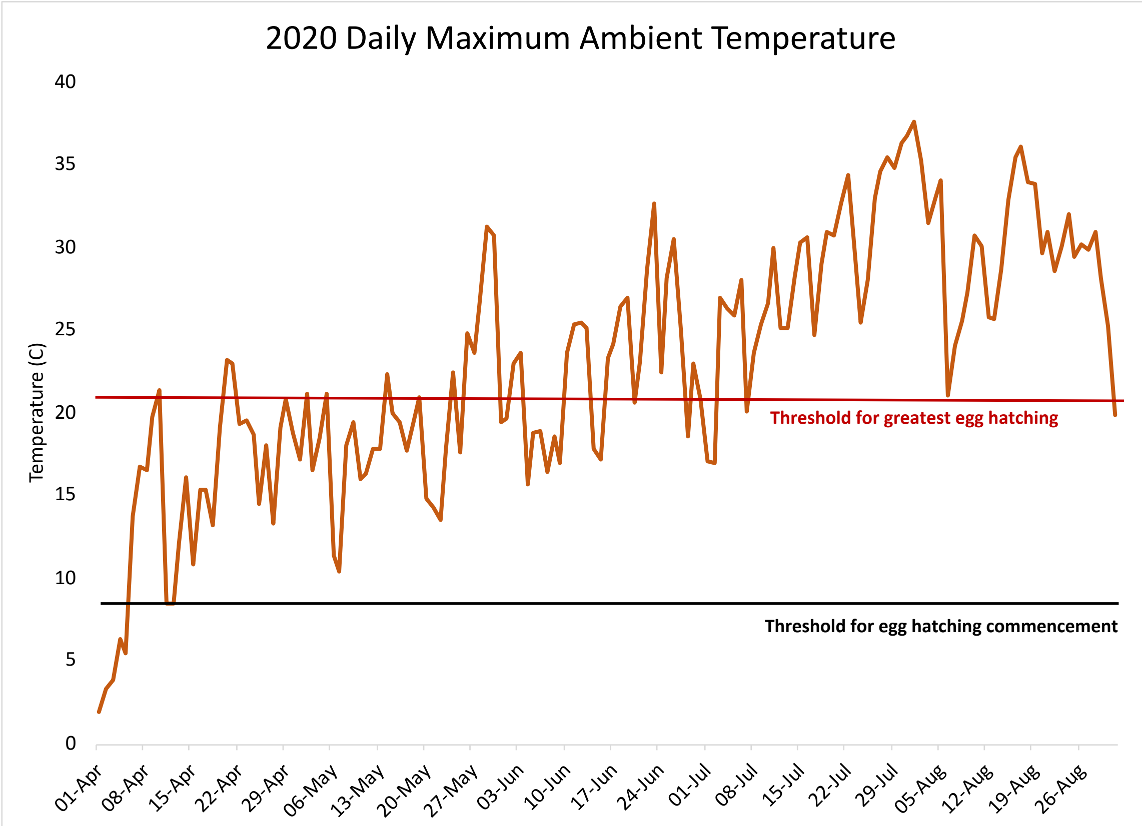

Figure 4. Maximum daily ambient temperatures (C) as recorded at the Kootenay River gauge at Fort Steele (ID: 08NG064) 01 April – 31 August 2020. Lower line illustrates threshold at which *Ae. sticticus* eggs commence hatching; upper red line illustrates threshold at which most *Ae. sticticus* eggs hatch according to Trpis and Horsfall (1969).

Locally, the 2020 season began with lower-than-normal ambient temperatures for April. However, given that April temperatures were well above those noted as being sufficient for hatching, floodwater mosquito eggs within the Wasa, Ta Ta Creek, and Skookumchuck area were likely activated within April if exposed to flooding conditions (Figure 4). It's important to note that water temperature, which experiences a delay in the warming or cooling trend by a couple of weeks, is correlated with dissolved oxygen content. As water temperatures rise, dissolved oxygen levels decrease, which ultimately triggers mosquito egg hatching if eggs have been appropriately conditioned by other environmental factors (Horsfall 1956). Thus, while possible floodwater larval hatching occurred in early April, the development at cooler temperatures would have been notably slow (Trpis and Horsfall 1969). The potential for larval development in April, is the primary reason for site monitoring commencement in April.

Local ambient temperatures in May were warmer and closer to the most favourable larval development threshold (Figure 4). Appropriately, larval treatments began in mid-May following a late-April spike in ambient temperature. Ambient temperatures in late May were ideal for floodwater mosquito hatching conditions.

Local ambient temperatures continued to increase through June, with multiple days exceeding 30ºC in maximum daily temperature (Figure 4). High water and high ambient temperatures in June resulted in increased floodwater mosquito hatching and larval development. Larval treatment amount and frequency were directly related to the increased ambient temperatures in June.

Ambient temperature does not directly relate to floodwater larval mosquito abundance after the Kootenay River levels measurably and consistently recede, due to lack of water as a cue for hatching. Regional Kootenay River levels markedly receded in July, meaning that the direct relationship between ambient temperature and floodwater mosquito development dissolved. However, ambient temperature does reduce the lifespan of adult mosquitoes (Ciota et al. 2014). Thus, any floodwater mosquitoes that successfully emerged during peak River levels, would have had a reduced lifespan with the heightened ambient temperatures into late July and August (Figure 4).

High local ambient temperature does provide hatching cues to container mosquito species (e.g, *Culex pipiens*) at the height of the summer. Thus, localized adult mosquito annoyance due to container mosquito presence may have occurred in July and August. Container mosquito habitats near residential homes can be created throughout the summer whenever water is coupled with high ambient temperatures. MBL technicians regularly inform residents that container mosquito species can be reduced around homes by ensuring their environments are either free of water or refreshed frequently.

River Levels

Within the Wasa/Ta Ta Creek/Skookumchuck area the majority of floodwater mosquito development sites are found along the flooding corridor of the Kootenay River. As the presence of water and associated dissolved oxygen levels are hatching cues for floodwater mosquito eggs, tracking the regional river levels provides predictive capabilities with regards to mosquito larval development.

The consistent rise of the local Kootenay River (Fort Steele gauge; 08NG065) began with a large pulse of the freshet in mid-April (Figure 5). Variable warming and cooling stints occurred throughout later April and most of May within the East Kootenay Basin, resulting in fluctuating freshet input to the Kootenay River system. A warming trend in late-May occurred across the southern portion of BC. The melting effect of this trend within the East Kootenay Basin and considerable precipitation led to the regional Kootenay River peak on 1 June at 4.45 m. (Figure 5).

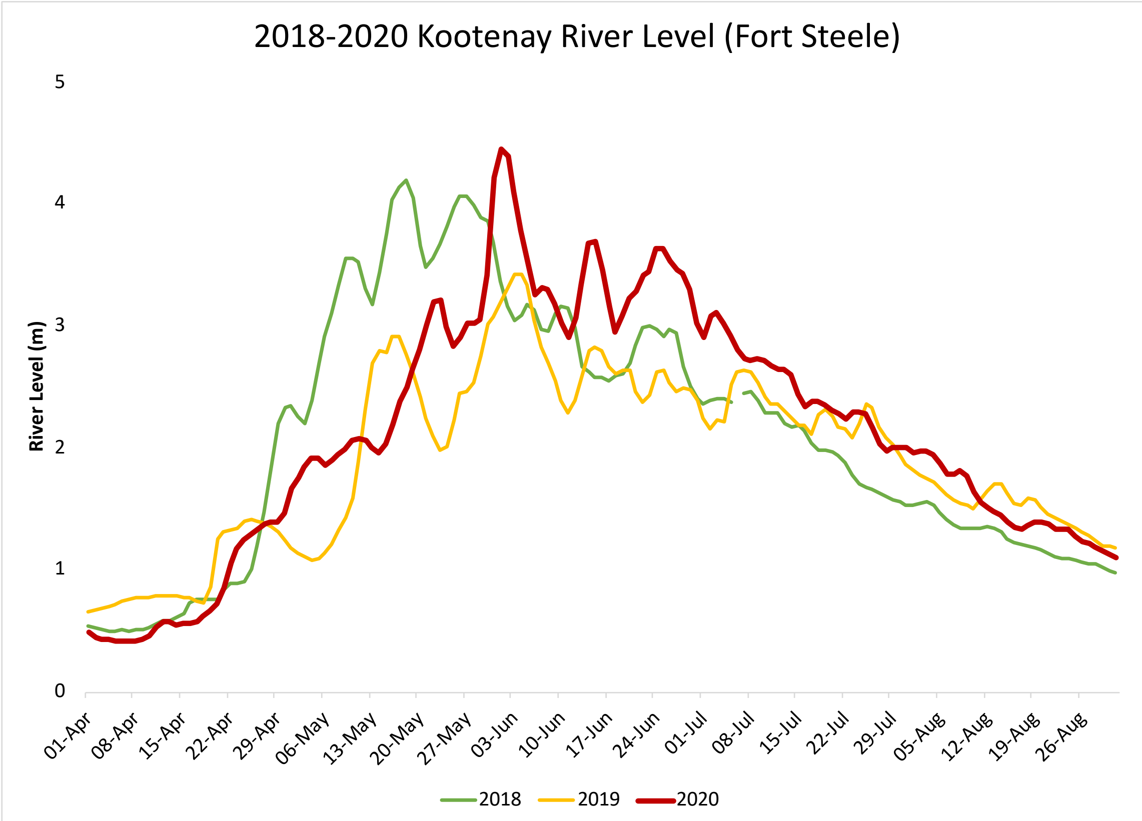

Figure 5. 2020 Kootenay River levels (m) as recorded at the Fort Steele gauge (08NG065; red) with 2018 and 2019 Kootenay River levels (01 April – 31 August).

Regional river peaks relative to those of 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 the 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. Figure 5 shows the Kootenay River's levels since 2018. The peak of the local Kootenay River in 2020 was nearly a metre higher than the 2019 peak and approximately 0.2 metre higher than the 2018 peak. Of note, the 2020 Kootenay River peak on 1 June was the highest recorded peak at Fort Steele in at least seven years. As opposed to 2019, all mosquito development sites in the Wasa, Ta Ta Creek, and Skookumchuck area were wet at peak Kootenay River levels. Thus, 2020 peak Kootenay River levels likely triggered an abundance of dormant eggs to hatch.

When river levels rise at high rates in the early portion of the season, the typically cool highly oxygenated water moving through the system doesn't provide sufficient hatching cues for floodwater mosquito eggs. During periods of increasing River levels in 2020, the regional Kootenay River rose at high rates from mid-May through early June (Figure 5). However, because those levels fluctuated and rose slowly between peaks, and also because peaks occurred during periods of higher local ambient temperature, it is likely that sufficient hatching cues were present to result in large-scale hatching events in 2020.

The later-than-normal freshet and fluctuating weather patterns in June led to additional, smaller peaks following the primary peak (Figure 5). The subsequent peaks also allowed mosquito development habitat to remain active longer than normal. In late June 2020, the East Kootenay Basin contributing to the Kootenay River was largely depleted of snow[8]. This depletion corresponds with a marked decline in regional Kootenay River levels by mid-July (Figure 5). River levels further decreased into August due to a lack of snowmelt and lower local precipitation accumulation. Thus, by mid-August many of the mosquito development sites were greatly reduced or dry.

Larval Control

Monitoring within Wasa/Ta Ta Creek/Skookumchuck began in late April, immediately following the initial seasonal rise in regional Kootenay River levels. 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 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 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 areas were within Skookumchuck between Kootenay Highway and Bradfrod Rd., near Wolf Creek, and near Lewis Creek (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.

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

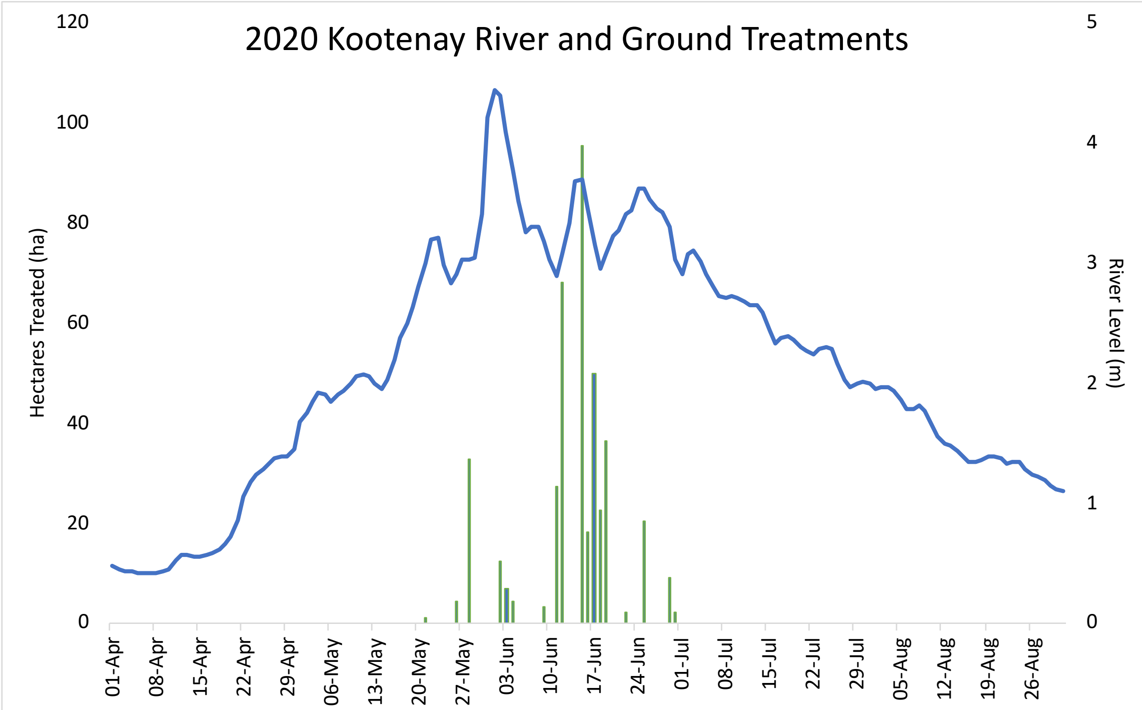

Figure 6. Kootenay River levels (m; Fort Steele gauge) with total mosquito development area treated by ground (ha) from 1 April – 31 August 2020. Note River levels (m) are recorded on the alternate y-axis.

The first ground treatment occurred on 21 May (Figure 6). Treatments increased following the initial Kootenay River peak, but were primarily clustered in mid-June immediately following the primary River peak. It is likely that most floodwater mosquito eggs were triggered to hatch during the peak River levels and quickly developed given comparatively high ambient temperatures.

Relative to the lower peaks of preceding seasons, mosquito habitat was significantly increased in 2020 due to higher Kootenay River levels. The total area treated in 2020 was more than five times the area treated in 2019. The Kootenay River also peaked during a period of high ambient temperatures and precipitation. These variables contributed to the creation of a compound number of floodwater mosquito eggs hatching and ideal mosquito hatching environments. River levels started to consistently recede in early July. Ground treatments tapered off into late-June and the final ground treatment was conducted on 30 June (Figure 6). Although river levels remained high through July, treatments had successfully targeted the sole seasonal mosquito development events for univoltine floodwater mosquito species.

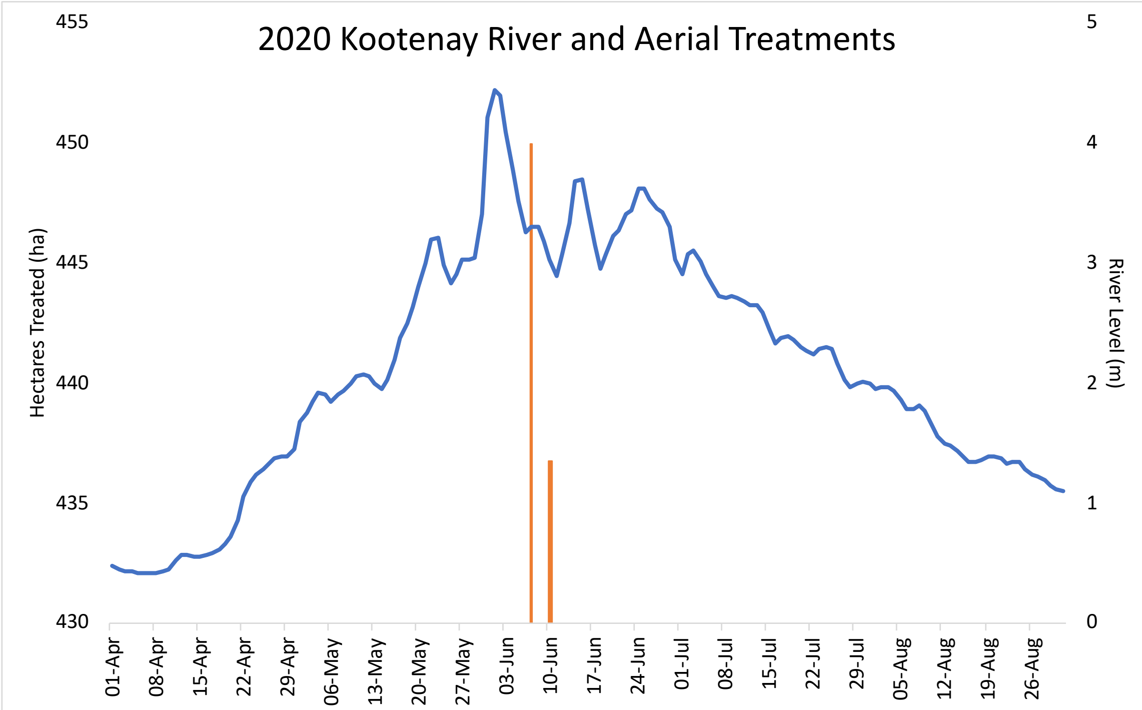

Figure 7. Kootenay River levels (m; Fort Steele gauge) with total mosquito development area treated aerially (ha) from 1 April – 31 August 2020. Note River levels (m) are recorded on the alternate y-axis.

Aerial treatments were also clustered around early June, immediately following the primary peak in regional Kootenay River levels (Figure 7). Two aerial treatment days occurred within the Wasa, Ta Ta Creek, and Skookumchuck area in 2020 on 7 and 10 June. Aerial treatments largely took place along the foreshore and associated seepage sites of the Kootenay River from the Wolf Creek area to south of Lewis Creek. Appendix II provides a map depicting where and how frequently aerial treatments and ground treatments took place in 2020. In certain cases, hexbins denoted as 'Non-Detected' or 'Low' do have treatments associated with them. 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 419 ha was treated by ground, equating to a total of approximately 1,674 kg of granular Aquabac® used (Table 1). 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 approximately6 kg/ha using the granular product and 1,000 ml/ha using the liquid product. A total of 887 ha was treated by air, equating to a total of 2,621 kg of granular Aquabac® and 450,000 ml of liquid Aquabac® (Table 1). No known sites were missed in 2020 and no new sites were discovered. Of note, the efficacy with the liquid Aquabac® was considerably high (anecdotally close to 100%). The use of the liquid product also reduced transport and storage challenges associated with the granular product. Future applications using liquid Aquabac® will likely include ground-based operations. Appendix III shows more specific information about site, treatment timing, and extent of treatment for both ground and aerial treatments.

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

	April	May	June	July	August
Ground (ha)	0	38.7	379.9	0	0
Aerial (ha)	0	0	886.7	0	0
TOTAL	0	38.7	1266.7	0	0

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

Wasa/Ta Ta Creek/Skookumchuck residents have multiple venues to lodge calls or emails with MBL. MBL has a company-maintained Mosquito Hotline (877-986-3363) and email form, outlined prominently on the contact tab of the MBL website (www.morrowbioscience.com). Additionally, residents may interact with MBL staff through social media platforms.

The total number of calls received from Wasa, Ta Ta Creek, and Skookumchuck area in 2020 was four (4). Of those, three (3) were concern calls regarding high levels of adult mosquitoes. The other call was to request that Bummer's Wetland be treated. Three (3) concern emails were received.

The high, sustained Kootenay River levels and the extensive untreated area immediately proximate to the Wasa, Ta Ta Creek, and Skookumchuck mosquito program are believed to have contributed to high adult mosquito abundance within the program purview. The Bummer's Wetland area is a dedicated conservation area, within which mosquito treatments are not allowed. Valley winds are capable of dispersing adult mosquitoes long distances and can inundate the Wasa, Ta Ta Creek, and Skookumchuck area during summers with high water, like 2020. Residents are aware of this specific contribution of adult mosquitoes to their areas.

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

Image 3. 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 highest reach for a post most relevant to the Wasa, Ta Ta Creek, Skookumchuck 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 Morrow BioScience website (www.morrowbioscience.com) has 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).

The Wasa, Ta Ta Creek, and Skookumchuck area program manager for MBL, Kendra Lewis, was interviewed by 102.9 FM 'The Drive' radio hosts on 5 June. The interview included an update on mosquito control activities occurring within the program purview and also included tips to reduce mosquito breeding habitat around private properties. The interview aired during the morning and evening news hours. Additionally, MBL staff members provided interviews to CTV (July 3) and Global News (July 10). Both television interviews described the reasons lending to high river levels within southern BC 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[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 October 4, 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 September 22, 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

[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

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.

Program Reminders

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

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

[12] https://www.healthlinkbc.ca/health-feature/zika-virus

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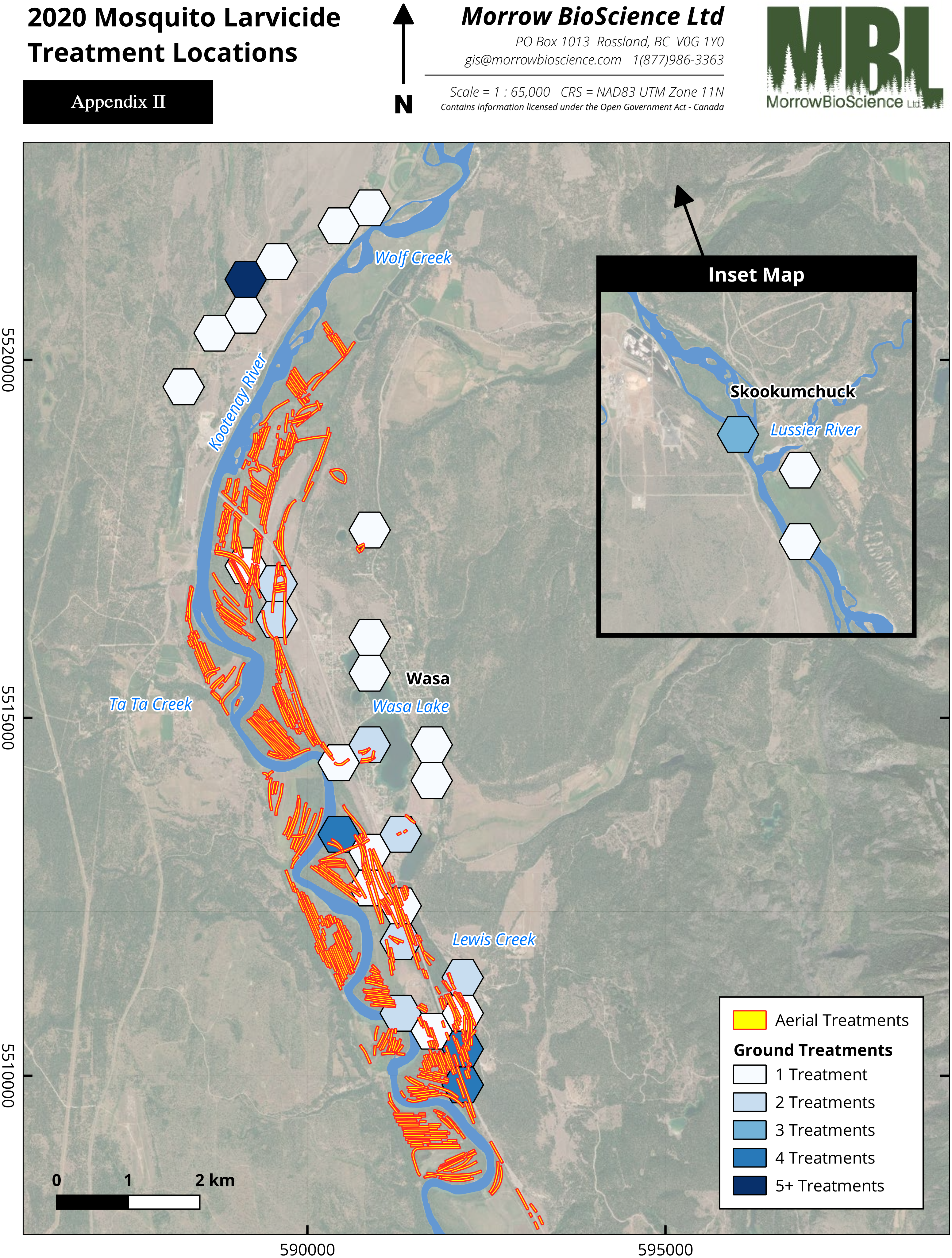
2020 Mosquito Larvicide Treatment Locations

Appendix II

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

Scale = 1 : 65,000 CRS = NAD83 UTM Zone 11N



2020 Mosquito Larvicide Treatment Locations

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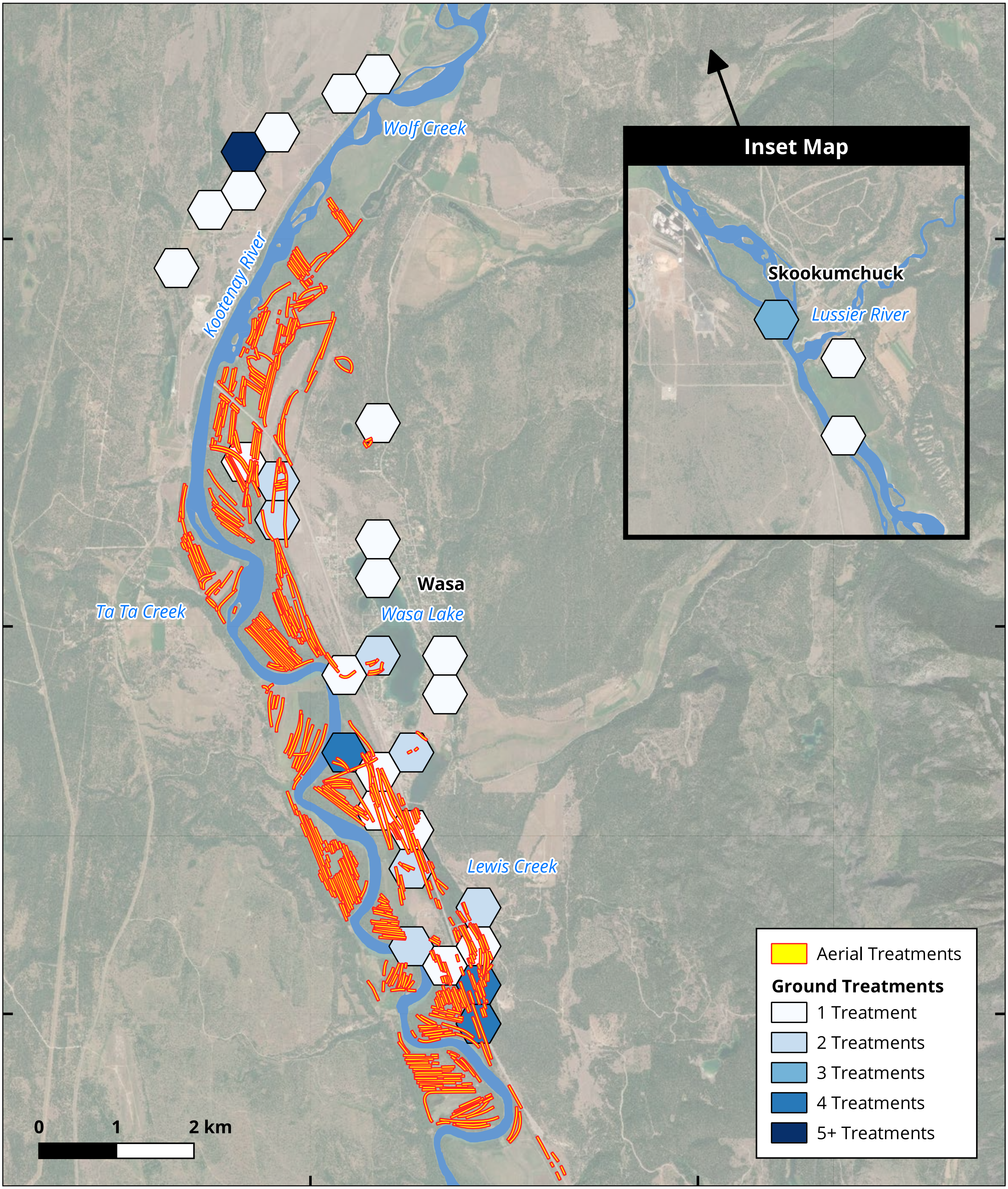

Appendix III. 2020 treatment data (kg, ha) by site and date for all ground (A) and aerial (B) treatments

III-A: Ground Treatments

Treatment Date	Site	Site Code	Treatment Amount (Kg)	Treatment Area (Ha)
2020-05-21	Skookumchuck Bridge	RDEK-048	4.55	1.14
2020-05-26	Skookumchuck Bridge	RDEK-048	18.20	4.55
2020-05-28	Skookumchuck Bridge	RDEK-048	4.55	1.14
2020-05-28	Bear Claw	RDEK-050	127.40	31.85
2020-06-02	Moans Road Railway Bed	RDEK-044	13.65	3.41
2020-06-02	Sawdust Pile	RDEK-018	36.40	9.10
2020-06-03	Wasa Lake	RDEK-020	9.10	2.28
2020-06-03	Ashram Slough	RDEK-005	18.20	4.55
2020-06-04	Corner of dump road		4.55	1.14
2020-06-04	Wasa Lake	RDEK-020	4.55	1.14
2020-06-04	Ashram Slough	RDEK-005	9.10	2.28
2020-06-09	River corner north of river road		4.55	1.14
2020-06-09	River corner north of river road		9.10	2.28
2020-06-11	Collins	RDEK-030	36.40	9.10
2020-06-11	Muskrat Ranch	RDEK-042	18.20	4.55
2020-06-11	Whites	RDEK-027	18.20	4.55
2020-06-11	Highway Slough	RDEK-003	18.20	4.55
2020-06-11	Corner of dump road		18.20	4.55
2020-06-12	Thunderhoof north next to railway bed	RDEK-058	18.20	4.55
2020-06-12	Collins	RDEK-030	36.40	9.10
2020-06-12	Wasa Lake	RDEK-020	18.20	4.55
2020-06-12	Thunderhoof overflow into trees	RDEK-067	54.60	13.65
2020-06-12	Thunderhoof north next to railway bed	RDEK-058	36.40	9.10
2020-06-12	Highway Slough	RDEK-003	18.20	4.55
2020-06-12	Praire Road	RDEK-001	54.60	13.65
2020-06-12	Praire Road	RDEK-001	18.20	4.55
2020-06-12	Highway Slough	RDEK-003	18.20	4.55
2020-06-15	Collins	RDEK-030	72.80	18.20
2020-06-15	Collins	RDEK-030	54.60	13.65
2020-06-15	Thunderhoof north next to railway bed	RDEK-058	127.40	31.85
2020-06-15	Graden Fo Road Fenced Bridge	RDEK-037	36.40	9.10
2020-06-15	South side of highway past bridge		91.00	22.75
2020-06-16	Bear Claw	RDEK-050	18.20	4.55
2020-06-16	South End Thunderhoof	RDEK-008	18.20	4.55
2020-06-16	Edge of Bummers	RDEK-013	36.40	9.10
2020-06-17	Thunderhoof railway flood		18.20	4.55
2020-06-17	Whites	RDEK-027	18.20	4.55
2020-06-17	Greenhouse	RDEK-022	18.20	4.55
2020-06-17	2 trees next to river	RDEK-062	127.40	31.85
2020-06-17	Rudded road to river from station house	RDEK-061	18.20	4.55
2020-06-18	2nd of 3 north wasa lakes		18.20	4.55
2020-06-18	Muskrat Ranch	RDEK-042	72.80	18.20
2020-06-19	Sweet Tooth #1	RDEK-028	18.20	4.55
2020-06-19	Muskrat Ranch	RDEK-042	127.40	31.85
2020-06-22	Green Subdivision	RDEK-045	9.10	2.28
2020-06-25	Green Subdivision	RDEK-045	18.20	4.55
2020-06-25	Muskrat Ranch	RDEK-042	18.20	4.55
2020-06-25	Muskrat Ranch	RDEK-042	36.20	9.05
2020-06-25	Muskrat Ranch	RDEK-042	9.10	2.28
2020-06-29	Muskrat Ranch	RDEK-042	18.20	4.55
2020-06-29	Muskrat Ranch	RDEK-042	4.55	1.14
2020-06-29	6529 Cotton Wood	RDEK-072	4.55	1.14
2020-06-29	Hanson Creek Channel	RDEK-024	4.55	1.14
2020-06-29	South End Thunderhoof	RDEK-008	4.55	1.14
2020-06-30	Moans Road	RDEK-043	9.10	2.28

III-B: Aerial Treatments

Treatment Date	Sites	Treatment Amount (Kg)	Treatment Amount (Ml)	Area Treated (Ha)
2020-06-07	Railroad switch old highway,1st of 3 North wasa lakes,2nd of 3 north wasa lakes,Collins,Collins Bridge,South of ducks unlimited ,West of Kootenay River by bridge,North side of highway past bridge ,South side of highway past bridge,East side of Kootenay river ,North of Collins		210000	210.0
2020-06-07	Bummers Highway Both Sides,Edge of Bummers,Corner of dump road,Praire Road,Chanell by highway,Lower Slough at Dump,Highway to Stationhouse,Channel within Prairie Road,Channel in Prairie Road,South End Thunderhoof,Highway Slough,Field off prairie road,Ashram Slough,Jameson,Center road off thunderhoof,Thunderhoof north next to railway bed,Thunderhoof overflow into trees,Thunderhoof Highway,Thunderhoof,Next to thunderhoof channel,Railway bridge by thunderhoof,In trees east of thunderhoof,Southend 2 trees 1st field,2 Trees 2nd Field,Budenhagen channels,Buddnagen,Rudded road to river from station house,2 trees next to river,2 Trees,Satilite dish field		240000	240.0
2020-06-10	Skookumchuck Bridge,Bear Claw,Green Subdivision,Muskrat Ranch,3rd of 3 lake north wasa,Dump road corner,Thunderhoof overflow into trees,South End Thunderhoof,Collins,South side of highway past bridge	2620.8		436.8

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.*

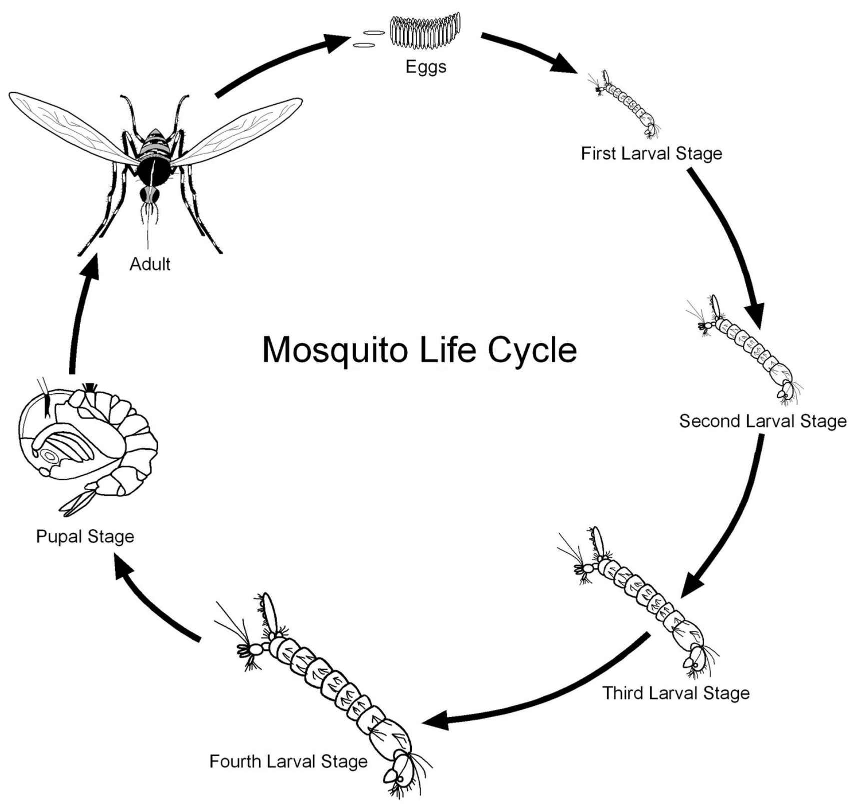
Significant local precipitation accumulation may also elevate local river levels. Local precipitation can temporarily increase seepage site levels, where mosquito development habitat is located. Thus, tracking local precipitation accumulation can aid MBL field staff with determining how long mosquito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

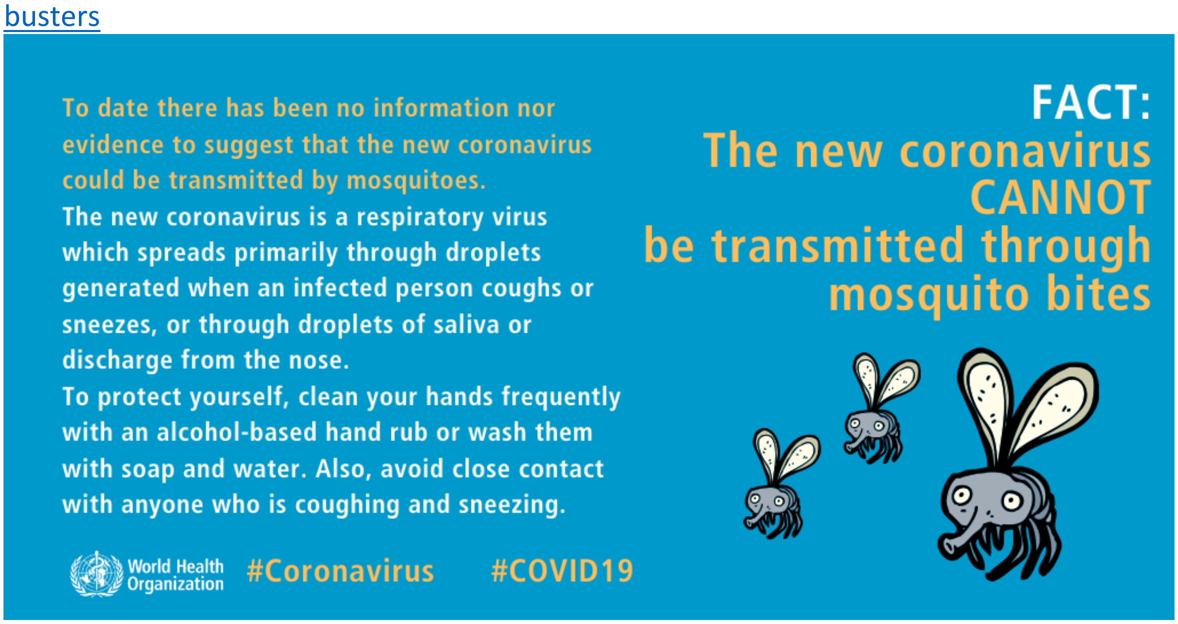
The BC Centre for Disease Control (BCCDC) website also contains health-related information for residents. The BCCDC site has a more detailed map of surveillance activity by region. It can be found at: http://www.bccdc.ca/health-info/diseases-conditions/west-nile-virus-wnv

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



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Frequently Asked Questions

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

MorrowBioScience Ltd.

Updated: 3 May 2020

Updated: 3 May 2020

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MorrowBioScience Ltd

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

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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

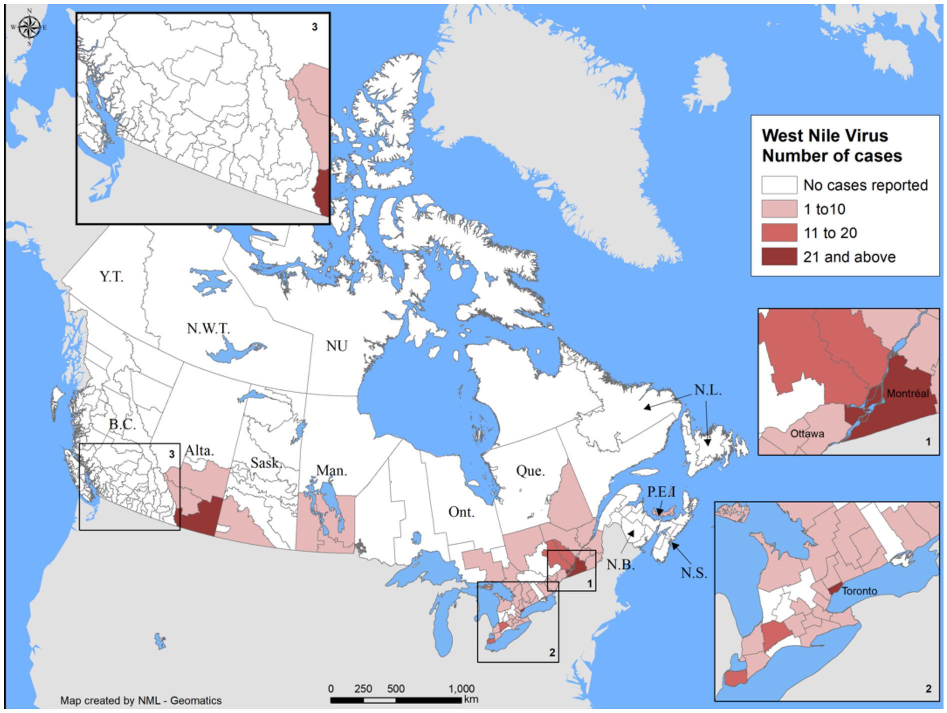

Image 2. 2018 distribution of human West Nile virus cases throughouth Canada (Health Canada)

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.

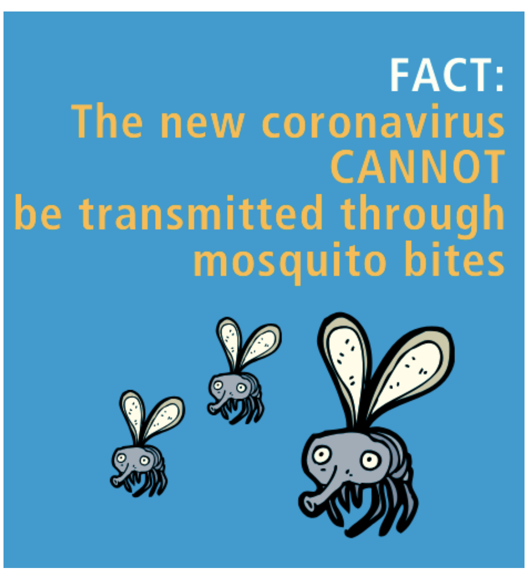

Image 3. World Health Organization myth busters

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.