REGIONAL DISTRICT OF EAST KOOTENAY
WASA, TA TA CREEK, SKOOKUMCHUCK
MOSQUITO CONTROL PROGRAM
2021 YEAR-END REPORT

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Executive Summary

Morrow BioScience Ltd. (MBL) has now completed the 25th consecutive year as mosquito control contractor for Wasa/Ta Ta Creek/Skookumchuck within the Regional District of East Kootenay (RDEK). This season, 2021, concludes the 5th 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 in the East Kootenay Basin and Upper Columbia Basin were 93 and 108 percent of normal, respectively. A regional warming trend in mid-April led to the start of the floodwater mosquito season. Warming events in mid-May and late-May/early-June resulted in the melting of all mid-elevation and some high-elevation snowpack. In response, the Kootenay River peaked on 4 June at 4.21 m. More-than-average precipitation was locally received in May and June, augmenting river levels, seepage sites, and micro-sites. A moderate abundance of floodwater mosquito eggs was detected in 2021. Although 2021 Kootenay River levels were high, they did not exceed 2020 peak levels. In most areas of the program, there was not a compounded number of mosquito eggs. However, water was found in new areas in 2021 due to the removal of a flood management structure in the Wasa region. This resulted in the need for additional treatments. No known sites were missed in 2021. No concern calls or emails were received in 2021. No human-cases of West Nile virus or Zika virus were reported by the BC CDC this year.

Between 27 May and 7 July, a total of 1,890 hectares were treated by ground and air. This total is greater than 600 ha than the area treated in 2020. The high total treated area in 2021 is due to the new floodwater mosquito habitat created following the removal of the flood management structure in Wasa. Three days of aerial treatmetns were required following the peak in the Kootenay River. Ground and aerial treatment efficacy was assessed as high. 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. MBL revamped the company website in 2021, making it easier to locate resources and blogs. MBL staff provided a local interview to 102.9 FM ‘The Drive’ radio on 8 June. The interview 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

- On 1 April, the average snowpack in the East Kootenay Basin was 93 percent of normal and in the Upper Columbia was in 108 percent of normal.
- Notable warming events that contributed water to the regional Kootenay River occurred in mid-April, mid-May, late-May/early-June, and mid-late June.
- The snowpack in both was depleted by the end of June due to the heat dome that settled over much of British Columbia.
- Warming and cooling periods coupled with periods of higher-than-average precipitation accumulation resulted in multiple peaks to the regional Kootenay River in 2021.
- The peak Kootenay River level at the Fort Steele gauge occurred on 4 June at 4.21 m.
- The peak was lower than the 2020 peak by 0.24 m.
- Ground treatments started on 27 May and concluded on 7 July.
- A total of 174.5 ha was treated by ground (698 kg granular Aquabac®).
- Three aerial treatment days were conducted: 11, 12, 13 June.
- A total of 1,715.4 ha was treated aerially (6,862 kg granular Aquabac®).
- Almost 600 more ha were treated in 2021 than in 2020.
- The removal of a floodwater management structure in Wasa has resulted in the creation of considerable new floodwater mosquito habitat. Water was found in Wasa in areas that had never been flooded within MBL's tenure as mosquito control contractors for the Wasa/Ta Ta Creek/Skookumchuck program.
- New reaches of the program resulted in a high abundance of floodwater mosquito larvae that required additional treatments.
- One (1) Mosquito Hotline calls was received in 2021 and was designated as 'inquiry.
- No concern emails were received in 2021.
- The relatively low number of concern calls and emails is reflective of a lower water year in comparison to 2020 and effective treatments.
- MBL staff provided an interview to 102.9 FM 'The Drive' radio (8 June).
- 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 – 2021 – is the fifth of the contract.

The Wasa/Ta Ta Creek/Skookumchuck program involves dynamic floodwater mosquito habitat and considerable program reach during high-water years. These variables make the 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. Mileage was not recorded for this program in 2021. However, the accumulated mileage over the course of 2021 is estimated to be close to mileage recorded in 2020. Ground transportation mileage in 2020 was approximately 14,392 km.

Using mileage in 2020 as a proxy for mileage in 2021, the driving requirements for this program resulted 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. 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

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

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 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, resulting in an amplified 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 as the Kootenay River levels start rising in the spring. 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) are treated by applications of the microbial larvicide product Aquabac®. This product has the active ingredient *Bacillus thuringiensis israelensis* (Bti), which is carried in a corncob formulation. The mode of action for Bti inherently includes a high degree of species selectivity. 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, it causes considerable damage to the larval gut wall and quickly results in 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 treatments use the same pesticide as ground applications, although sometimes with a higher application rate to permeate canopy cover. High water years, or years in which treatments are required in between unstable weather conditions, may require multiple days to complete aerial treatment campaigns.

It is important to time treatments according to the correct stage of larval development (i.e., 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 the ecosystem.

Environmental Conditions

The three primary environmental conditions that affect the Kootenay River levels throughout the mosquito season (i.e., April – August) 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 regulated by the freshet released from the East Kootenay Basin and, to a lesser degree, the Upper Columbia Basin during the mosquito season. 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. When snowpack within the East Kootenay Basin and Upper Columbia Basin exceed 100 percent of normal, higher-than-average Kootenay River levels are expected during the mosquito season.

In April, the East Kootenay Basin and Upper Columbia Basin had a snowpack of 93 and 108 percent of normal, respectively[2]. The Upper Columbia Basin received additional snow in the early half of April and the East Kootenay Basin received additional snow in the latter half of April. The April augmentation of the snowpack for both basins resulted in peak Snow Water Equivalent (SWE) values for those basins in 2021.

[2] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/river-forecast/2021_apr1.pdf

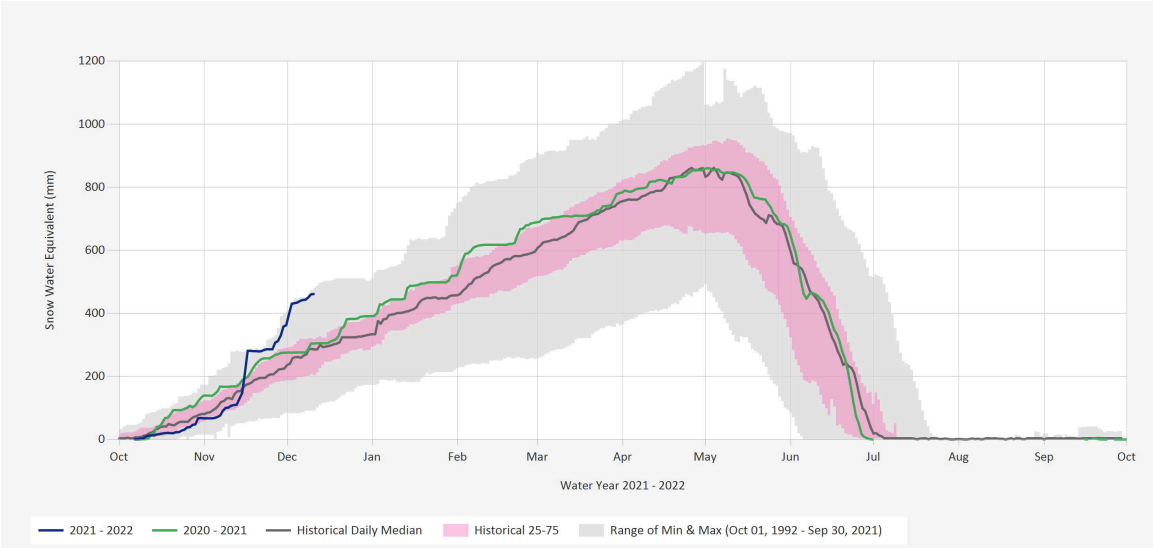

Figure 1. Automated Snow Weather Station data from Floe Lake (ID: 2C14P). Green line represents data from 2020-2021.

A ridge of high-pressure settled over much of the province from 14-18 April and led to unseasonably warm ambient temperatures and some low-elevation snowmelt[3]. The weather in May was generally stable and both contributing basins' snowpack was not measurably augmented in that month. In fact, warm temperatures in mid-May and late-May/early-June within the basins resulted in middle and some high-elevation snowmelt. A brief stint of cool weather slowed the regional snowmelt in mid-June. The 15 June Snow Survey and Water Supply Bulletin note that the average snowpack within the East Kootenay Basin Upper Columbia Basin was 110 and 133 percent of normal, respectively[4]. The River Forecast Centre suggested cautious interpretation of the reported percentage. However, the considerably high 'percent of normal' snowpack remaining as of 15 June reflected the rarity of late-season snowpack persistence. Record-setting heat was recorded for much of the province in late June. The heat dome effect resulted in the quick and complete depletion of all high-elevation snow in both basins.

The Floe Lake snow survey station (ID: 2C14P) is upstream of the program purview (Figure 1). It serves as a representative site for the regional snowmelt trajectory. The Snow Survey data show a brief melting stint toward the end of April[5]. It also shows the first measurable melting trend in mid-May, with the lower and middle-elevation SWE dropping significantly. The data show the impact of the heat dome in late June, resulting in the depletion of the Floe Lake station's snowpack by the end of June (Figure 1). Other snow survey stations throughout the Upper Columbia Basin show similar trends[6]. Thus, by early July any fluctuations in the regional Kootenay River levels were likely not due to regional snowmelt contributions.

[3] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/river-forecast/2021_may1.pdf
[4] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/river-forecast/2021_june15.pdf
[5] https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-science-data/water-data-tools/snow-survey-data
[6] https://governmentofbc.maps.arcgis.com/apps/webappviewer/index.html?id=c15768bf73494f5da04b1aac6793bd2e

Regional Precipitation

Extensive temporally and spatially-concentrated precipitation accumulation may elevate regional Kootenay River levels. Local precipitation can also temporarily augment seepage site levels and create micro-mosquito development sites (e.g., hoof prints, car tracks) where floodwater mosquito development habitat is located. Tracking local precipitation accumulation can aid MBL field staff in determining when mosquito sites become active and how long sites may require management. The Cranbrook Airport Auto weather station (ID: 1152106) provides both historical precipitation accumulation averages (i.e.,1981 – 2010) and current-year totals, allowing for the comparison between the two. This comparison facilitates some level of prediction regarding larval mosquito hatching and treatment timing requirements. When more than average precipitation is received within peak hatching months, seepage site levels may be higher or sustained for longer. Both scenarios may lead to additional floodwater mosquito egg hatches.

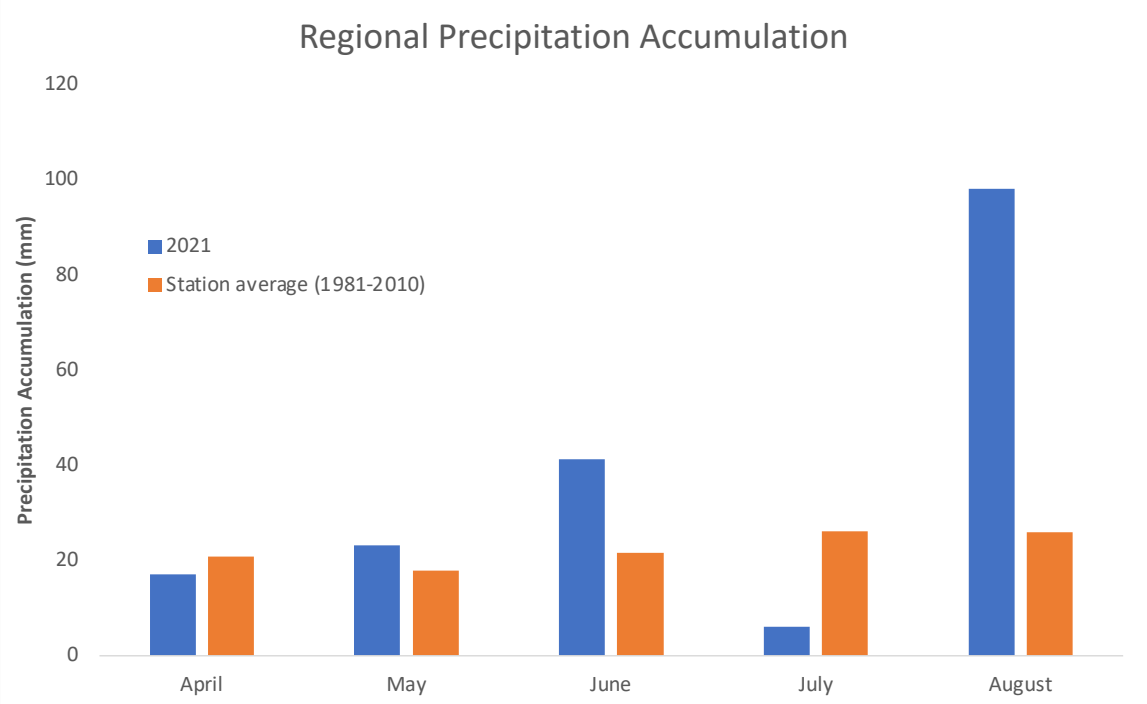

Figure 2. Precipitation values (rainfall and snow accumulation; mm) recorded at the Cranbrook Airport Auto weather station (Climate ID: 1152106) for 01 April – 31 August 2021 (blue) and average station precipitation values (1981-2010; orange).

The precipitation received at the Cranbrook Airport Auto weather station during the 2021 mosquito season ranged from below average to significantly greater-than-average (Figure 2). The precipitation received in April was lower than the station average. Precipitation received in May was higher than the monthly station average. While precipitation received in April occurred well in advance of the season's freshet and, thus, impacted the regional Kootenay River minimally, it is likely that precipitation received in May augmented rising Kootenay River levels. This impact may have translated to an increased reach of mosquito development sites within the program purview.

Regional precipitation in June was almost twice the station average (41.4 mm; Figure 2). The majority of precipitation was received in mid and late-June. Precipitation received during those time periods may have contributed to maintaining regional Kootenay River levels, but it is unlikely that precipitation received in June measurably augmented the Kootenay River peak. It is likely that precipitation received in June created or impacted micro-mosquito development sites.

Precipitation received to the area in July was notably low (Figure 2). However, precipitation accumulation in August (98.1 mm; Figure 2) was almost four times the historical accumulation for the month. At that point in the season, precipitation is of little consequence to the regional river levels and associated mosquito development sites because the univoltine floodwater mosquito species had already hatched and/or floodwater mosquito development habitat had been reduced. However, it's possible that precipitation received in August did create habitat for container mosquito hatching. Thus, adult mosquito presence toward the end of the season was likely due to container mosquito hatches, not floodwater mosquito species in certain areas.

Ambient Temperature

Ambient temperature, both locally and within the contributing snow basin, is an important variable to track. Local ambient temperature fluctuations from April through August can affect mosquito egg hatching, larval development rates, adult dispersal, and adult survival in the Wasa, Ta Ta Creek, and Skookumchuck region. Ambient temperature within the East Kootenay Basin and Upper Columbia Basin dictates the commencement and often the intensity of the freshet.

East Kootenay and Upper Columbia Basin Temperatures

Ambient temperatures for April were generally normal within the East Kootenay and Upper Columbia basins. The 1 May Snow Survey and Water Supply Bulletin[7] noted that temperatures averaged between -2ºC to +2ºC for the month. This normal range was recorded despite the ridge of high pressure from 14-18 April that included warmer temperatures and resulted in low-elevation snowmelt.

Ambient temperatures in May within the basins were considered slightly above normal in comparison to monthly averages[8]. Warming and cooling events both occurred during the month. Notable warming stints took place in mid and late-May/early June, resulting in melting events in both basins. The late-May/early June ambient temperatures recorded within that basin would lead to a pulse contributing to increased regional river levels (i.e., 1-7 June) and the official peak in the Kootenay River.

Weather within much of the province during the first week of June was dominated by a high-pressure system[9]. The following low-pressure system present slowed the high

[7] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/river-forecast/2021_may1.pdf
[8] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/river-forecast/2021_june1.pdf
[9] https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/river-forecast/2021_june15.pdf

elevations snowmelt within the East Kootenay and Upper Columbia basins. However, a strong high-pressure ridge was in place over most of the province in the latter half of June. The heat dome effect resulted in the shattering of many high-temperature records within the province and led to the depletion of high-elevation snowpack within both basins. The pulse of water from that melting event led to the secondary peak in the regional Kootenay River in the latter half of June. Temperature data are consistent with 2021 automated snow station data depicting snowmelt points correlating with regional ambient temperature spikes[10].

Local Temperatures

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 floodwater mosquito egg hatching will commence (Mohammad and Chadee 2011). Thus, local ambient temperature is a predictive tool when gauging floodwater egg hatch commencement. Local ambient temperature data are acquired from the Cranbrook Airport Auto weather station (ID: 1152106).

To illustrate the effect of ambient temperature on mosquito developmental benchmarks, Trpis and Horsfall (1969) exposed submerged eggs of a regionally common floodwater mosquito species, *Aedes sticticus*, to various constant air temperatures and recorded hatching success. Results revealed that eggs began to hatch at 8°C, although larval development was slow and survivorship was low. Eggs held at 21°C provided the optimal temperature, of the five temperatures tested, for hatching and larval development (Figure 3). While *Ae. sticticus* is not the sole floodwater species present in the Wasa, Ta Ta Creek, and Skookumchuck area, it is frequently caught in regional adult mosquito traps and serves as a representative species for control purposes.

[10] 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

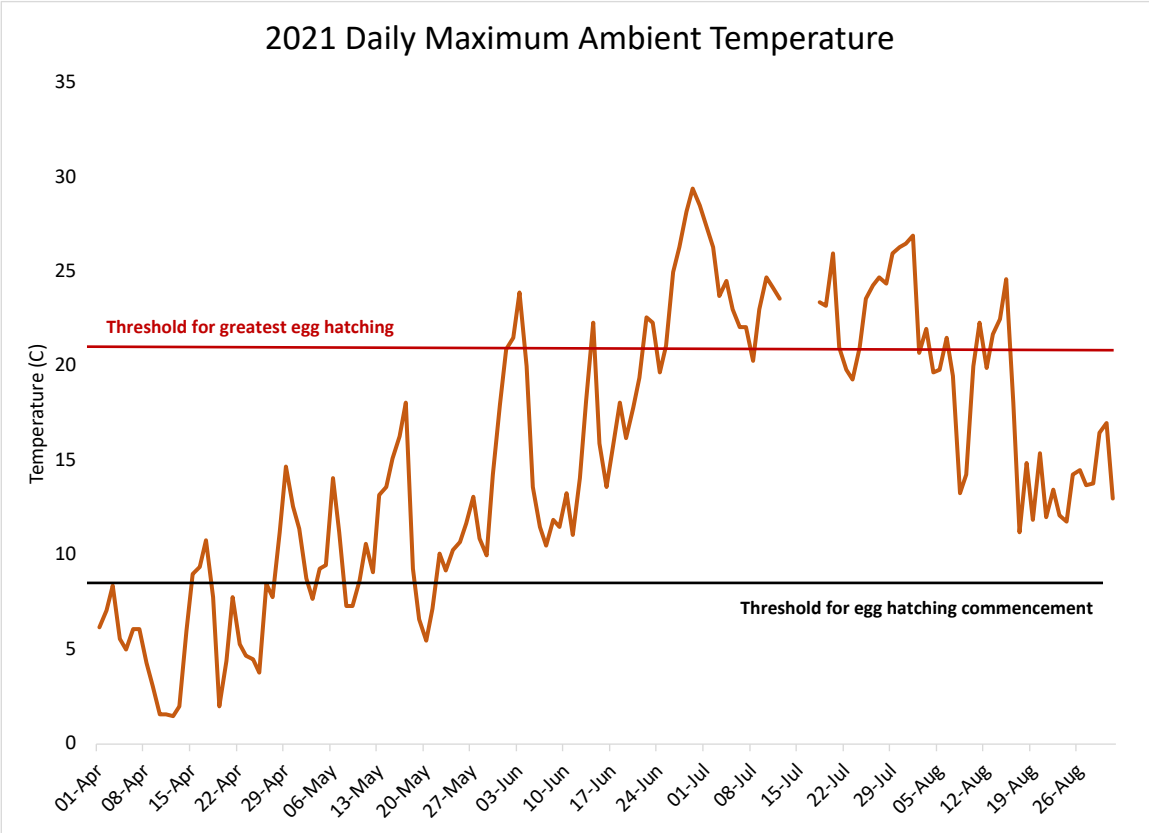

Figure 3. Maximum daily ambient temperatures (C) as recorded at the Cranbrook Airport Auto weather station (ID: 1152106) 01 April – 31 August 2021. Lower line illustrates threshold at which *Ae. sticticus* eggs commence hatching; upper red line illustrates threshold at which most *Ae. sticticus* eggs hatch according to Trpis and Horsfall (1969).

April ambient temperatures were sufficient to trigger floodwater mosquito egg hatching events if the eggs were exposed to flooding conditions (Figure 3). Mosquito egg development at that time of the season would have likely been slow and hatching success low. While temperatures in mid-April briefly surpassed the early threshold for floodwater mosquito egg hatching and survivorship, the regional river levels were low and, thus, most floodwater mosquito eggs were likely not exposed to water.

Local ambient temperatures in mid and late-May were relatively warmer and more favourable for floodwater larval mosquito development (Figure 3). Accordingly, hatching and larval development rates increased significantly in May. Ambient temperature decreased again around 7 June, slowing floodwater mosquito larval development. Ambient temperatures rebounded in mid-June and significantly increased in late June as the heat dome settled over most of the province. The heat dome facilitated further mosquito hatching and increased larval development rates. Because numerous floodwater development sites were at peak levels, the need to treat mosquito larvae in June was directly associated with ambient temperature.

Warmer-than-average ambient temperatures were documented from the latter half of June through mid-August. As regional river levels were also high at points within this timeframe, numerous mosquito eggs were exposed to ideal environmental hatching cues,

resulting in the need for large-scale treatment events. By mid-July, regional river levels were receding and ambient temperature was no longer directly related to floodwater larval mosquito abundance and treatments.

High local ambient temperatures 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 stagnant 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 low dissolved oxygen levels are hatching cues for floodwater mosquito eggs, tracking the regional river levels provides predictive capabilities regarding 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 4). Variable warming and cooling stints occurred throughout later April and early May within the East Kootenay and Upper Columbia basins, resulting in fluctuating freshet input to the Kootenay River system. A warming trend in mid and late-May/early-June occurred across the southern portion of BC. The melting effect of this trend within the associated basins and higher-than-average precipitation led to the regional Kootenay River peak on 4 June at 4.21 m. (Figure 4).

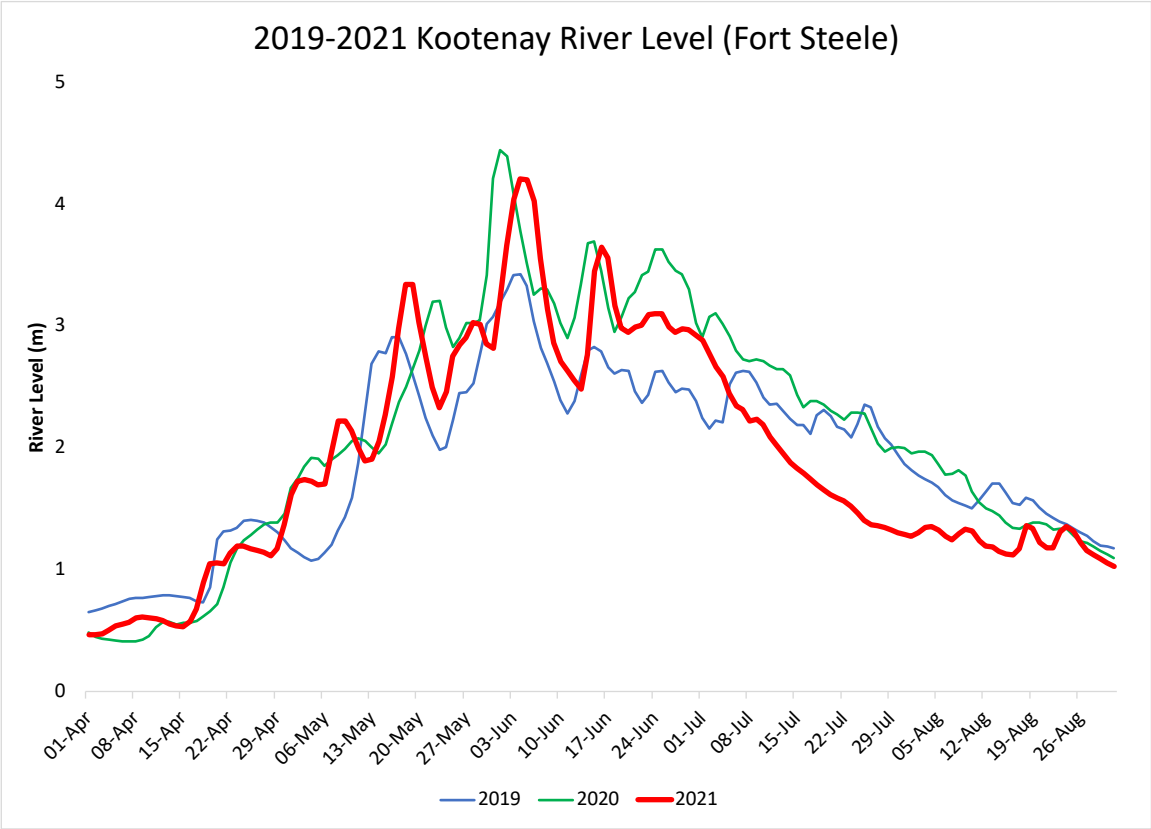

Figure 4. 2021 Kootenay River levels (m) as recorded at the Fort Steele gauge (08NG065; red) with 2020 and 2019 Kootenay River levels (01 April – 31 August).

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 4 shows the Kootenay River's levels since 2019. The peak of the local Kootenay River in 2021 was approximately 0.2 m lower than the 2020. Because of this difference, it is likely that 2021 peak Kootenay River levels did not trigger a compounded number of floodwater mosquito eggs to hatch. Although the river was lower than 2020 peak levels, mosquito development sites in the Wasa, Ta Ta Creek, and Skookumchuck area were wet at peak Kootenay River levels.

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. The Kootenay River rose at high rates from around May and early June (Figure 4). However, because those levels fluctuated and rose slowly between peaks, and 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 2021.

In late June, the East Kootenay Basin and Upper Columbia Basin were largely depleted of snow[11]. This depletion corresponds with a marked decline in regional Kootenay River levels during that time (Figure 4). River levels further decreased in early August due to a lack of snowmelt contribution. By mid-August many of the mosquito development sites were greatly reduced or dry with the further reduced Kootenay River levels. The late-August River level fluctuation was likely a result of the significantly high regional precipitation received within that timeframe.

Larval Control

Monitoring within Wasa/Ta Ta Creek/Skookumchuck began in early May, immediately following the initial seasonal rise in regional Kootenay River levels. Appendix I shows a map of average larval densities found throughout the 2021 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. The areas with highest recorded larval abundance amongst known areas were within Skookumchuck near the confluence of the Lussier River and Kootenay River, northwest of Wasa Lake Provincial Park, and near Lewis Creek and Prairie Rd. (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.

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

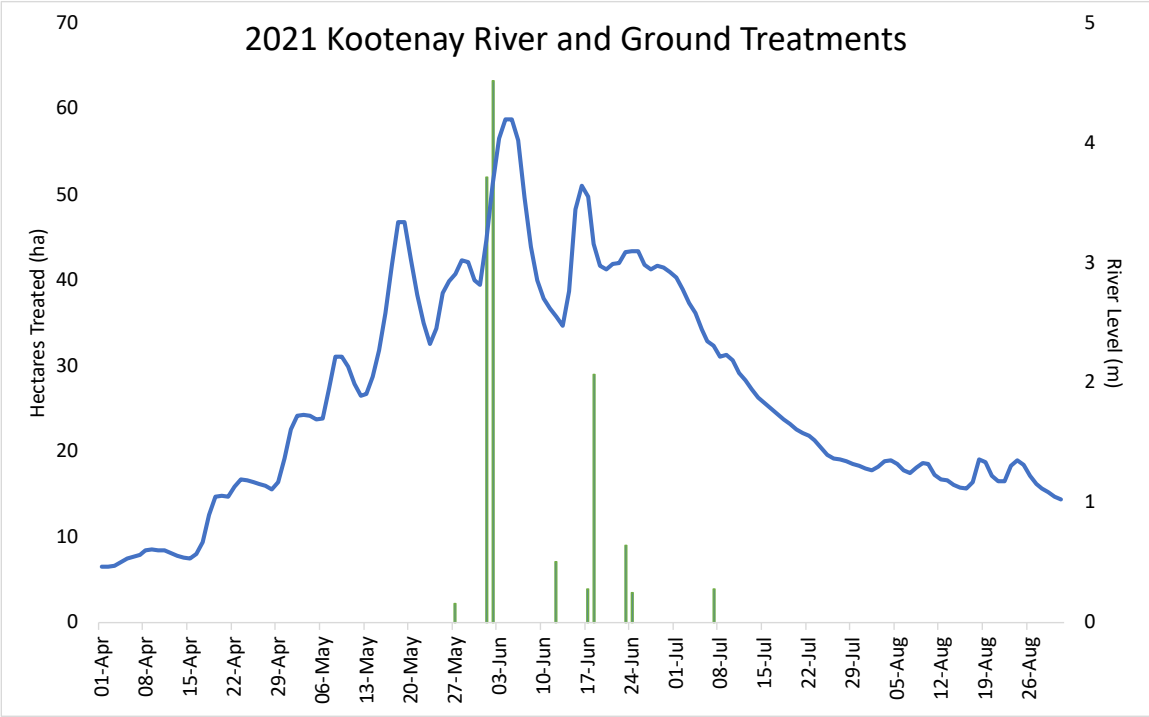

Figure 5. Kootenay River levels (m; Fort Steele gauge) with total mosquito development area treated by ground (ha) from 1 April – 31 August 2021. Note River levels (m) are recorded on the alternate y-axis.

The first ground treatment occurred on 27 May (Figure 5). A small treatments took place following the initial Kootenay River peak, but the largest ground treatments were clustered in late-May/early-June immediately prior to and 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.

Floodwater mosquito habitat was extensive in 2021. The total area treated in 2021 was approximately 560 ha more than was treated in 2020. Following the removal of a floodwater management infrastructure in Wasa a number of years ago, floodwater now enters new areas of the program and varies depending on the year. Floodwater moved differently in that area in 2021 than it did in 2020, resulting in new areas that required treatment in 2021. Certain areas had likely not been wetted in numerous seasons, thus it is possible that those areas of Wasa experienced a compounded number of floodwater mosquito hatches in 202. River levels started to consistently recede in early July. Ground treatments tapered off by mid-July and the final ground treatment was conducted on 7 July (Figure 5).

Ground treatments were applied at a rate of 4 kg/ha. A total of 174 ha was treated by ground, equating to a total of approximately 700 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.

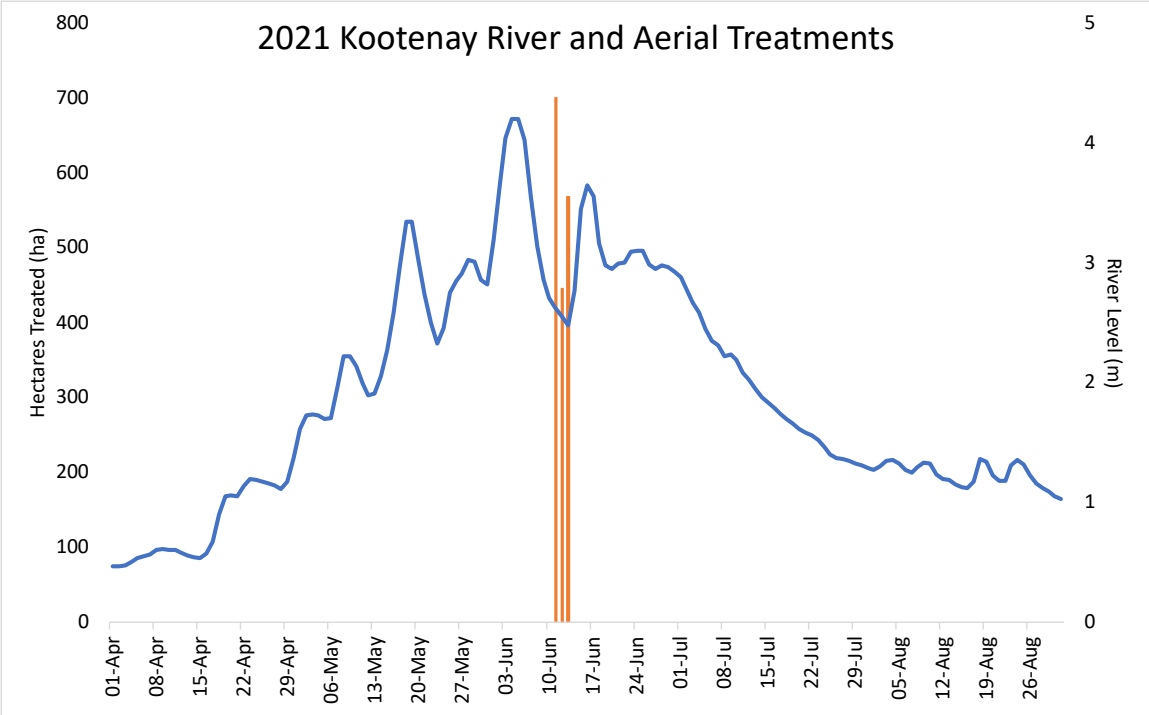

Figure 6. Kootenay River levels (m; Fort Steele gauge) with total mosquito development area treated aerially (ha) from 1 April – 31 August 2021. Note River levels (m) are recorded on the alternate y-axis.

Aerial treatments were also clustered around mid-June, immediately following the primary peak in regional Kootenay River levels (Figure 6). Three aerial treatment days occurred within the Wasa/Ta Ta Creek/Skookumchuck area in 2021 on 11, 12, and 13 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. Additional treatments were required in Wasa near that area where the flood management structure was removed. Appendix II provides a map depicting where and how frequently aerial treatments and ground treatments took place in 2021. 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.

Aerial treatments were conducted using granular Aquabac®. Aerial treatments were applied at a rate of approximately 4 kg/ha. A total of 1,715 ha was treated by air, equating to a total of 6,860 kg of granular Aquabac® (Table 1). No known sites were missed in 2021. Multiple new areas have been discovered in the previous years as MBL staff learns how water moves within the Wasa region following the removal of the flood management infrastructure. New areas of the program are now considered viable floodwater mosquito habitat as a result of the infrastructure removal. Appendix III shows more specific

information about site, treatment timing, and extent of treatment for both ground and aerial treatments.

Table 1. 2021 treated area (ha) by method (i.e., ground vs. aerial) and month from April - August.

	April	May	June	July	August
Ground (ha)	0	2.25	168.2	4	0
Aerial (ha)	0	0	1715.4	0	0
TOTAL	0	2.25	1863.4	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 and to improve our communication techniques.

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. Additionally, residents may interact with MBL staff through social media platforms. One call and no emails were received from Wasa/Ta Ta Creek/Skookumchuck residents in 2021. The single call was designated as an ‘inquiry’, with the resident requesting that their property not be treated in 2021. The lack of concern calls or emails is likely due to increased treatment efforts and fewer floodwater mosquito eggs due to the higher peak levels of 2020. Calls and emails are returned within 24 hours of receipt if a phone number is provided.

Direct Communications

Direct communication between MBL staff and the public can occur in many situations. 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. An important outcome of these interactions can be the identification of new sites.

Image 2. MBL education outreach pamphlet.

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

Education Outreach

MBL maintains a presence on social media with a Facebook account (facebook.com/MorrowMosquito), Twitter account (@MorrowMosquito), and Instagram account (linked to Facebook) which are regularly updated. There are five goals for MBL's social media presence: 1) provide timely and up-to-date information regarding conditions pertinent to mosquito production, 2) relay MBL's current efforts to control mosquitoes, 3) inform the public about MBL's efforts at environmental sustainability, 4) provide the community with opportunities to get involved with related public events, and 5) offer a platform for mosquito-related discussion amongst program residents and the MBL team.

Facebook remains the primary avenue for MBL to disseminate mosquito-related information on social media. Regular updates on mosquito abundance began in early March. The total number of followers on the MBL Facebook page was 341 on 15 November. This number has increased by 11 since November 2020. Another way to

determine how many people are engaging with MBL's posts is by considering MBL's post 'reach'. In 2021, the maximum reach pertaining to the MVRD mosquito control program was 85 on 12 June and was in response to a posting about the aerial treatment event occurring in the region (Image 3). This maximum reach is significantly lower than that of 2020, potentially reflecting the lessened concern about adult mosquitoes given the relatively lower Kootenay River levels and associated nuisance mosquito abundance.

Image 3. Facebook post from 12 June 2021 showing aerial treatment efforts for the Wasa, Ta Ta Creek, and Skookumchuck area.

MBL Website

The MBL website (**www.morrowbioscience.com**) was launched in 2015 and redesigned in 2021 (Image 4). This site was developed to allow clients and the public to have access to information about MBL's background, activities, outreach, and company. To further support residents in contract areas, the homepage includes visible tabs for resources and the contact information. The 'Contact' tab allows users to directly send a message to MBL. Additionally, there are links to MBL's Facebook account and Twitter feed, so residents have access to real-time updates on MBL's activities.

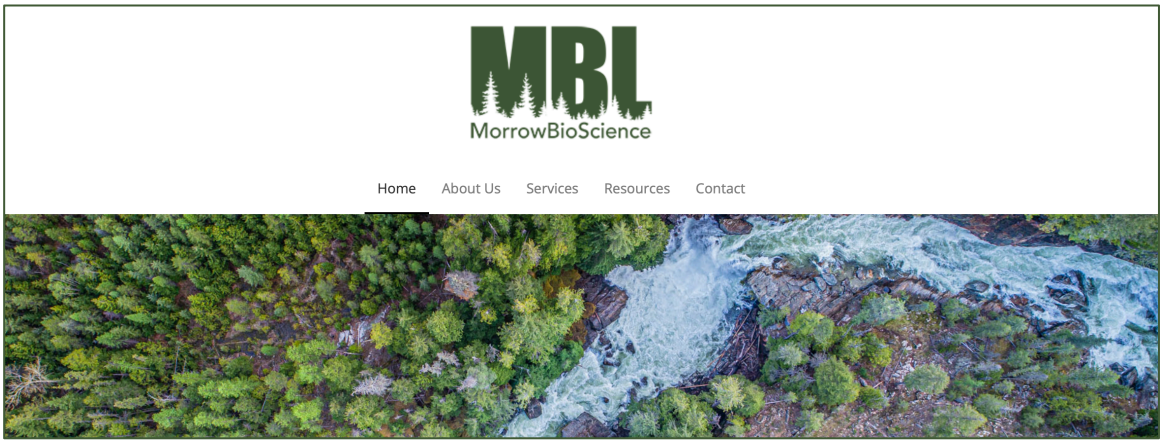

Image 4. Morrow BioScience Ltd. new homepage (www.morrowbioscience.com; April 2021)

Education Outreach

Given the continued provincial restrictions regarding large gatherings to reduce the spread of COVID-19, MBL relied on previously created virtually-available education outreach material instead of attending public events. As such, the MBL website (www.morrowbioscience.com) has highlighted two sets of FAQ documents focused on (1) mosquito biology and disease transmission and (2) the active ingredient used in control efforts (*Bacillus thuringiensis* var. *israelensis*). Both FAQ documents were provided to the CSRD program manager in April. Additionally, a blog dedicated specifically to mosquitoes and COVID-19 was published on the MBL website.

Following RDEK approval, a media release was distributed to a local radio station, 102.9 FM, The Drive. The MBL RDEK program manager, Kendra Lewis, was interviewed by The Drive radio hosts on 8 June. The interview included an update on mosquito control activities occurring in and around the Wasa, Ta Ta Creek, and Skookumchuck areas and also provided tips to reduce mosquito breeding habitat around private properties. The interview aired during the afternoon and evening news hours of 8 June.

West Nile virus Summary

Although floodwater mosquito species in Canada are not the main West Nile virus (WNv) vectors, it is important to remain current in regional mosquito-related diseases. Along with their partners, Health Canada compiles on-going provincially reported surveillance data of WNv cases in humans, animals, and mosquito pools between 1 January and 29 September. As of 12 October, no human case of WNv were reported to Health Canada from British Columbia[12]. Similarly, no horse or bird cases were reported from British Columbia within 2021. Of note, mosquito pool surveillance data are not reported to Health Canada from British Columbia and it is possible that other information was not reported by the BCCDC to Health Canada.

[12] https://www.canada.ca/en/public-health/services/publications/diseases-conditions/west-nile-virus-surveillance/2021/week-37-38-september-13-26.html

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 17 October, there were three human cases of WNv reported in Washington State; all were acquired in-state within counties in the southern area of the state[13]. Additionally, 51 mosquito pools and 11 horses/other mammals tested positive for WNv. No birds tested positive for WNv in 2021. Of note, historically high temperatures experienced throughout the Pacific Northwest from June through August contributed to a greater number of degree days and translated to an increase in state-wide WNv activity.

As of 17 October, 11 human WNv cases were identified in Idaho[14]. Additionally, multiple mosquito pools and animals tested positive for WNv. 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 2021. HealthLinkBC reports that no Zika cases have originated in Canada due to presumed lack of vector mosquito species[15]. There have been human Zika cases reported in Canada prior to 2021, 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 British Columbia. *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 British Columbia.

[13] http://www.doh.wa.gov/DataandStatisticalReports/DiseasesandChronicConditions/WestNileVirus
[14] https://www.cdc.gov/westnile/statsmaps/preliminarymapsdata2021/index.html
[15] https://www.healthlinkbc.ca/health-feature/zika-virus

2022 Program Recommendations

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

- Reconnaissance efforts should continue for floodwater mosquito development sites within the area where the flood management infrastructure was removed.

- Notify the Ministry of Environment of the RDEK intent to treat mosquitoes in 2022 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.

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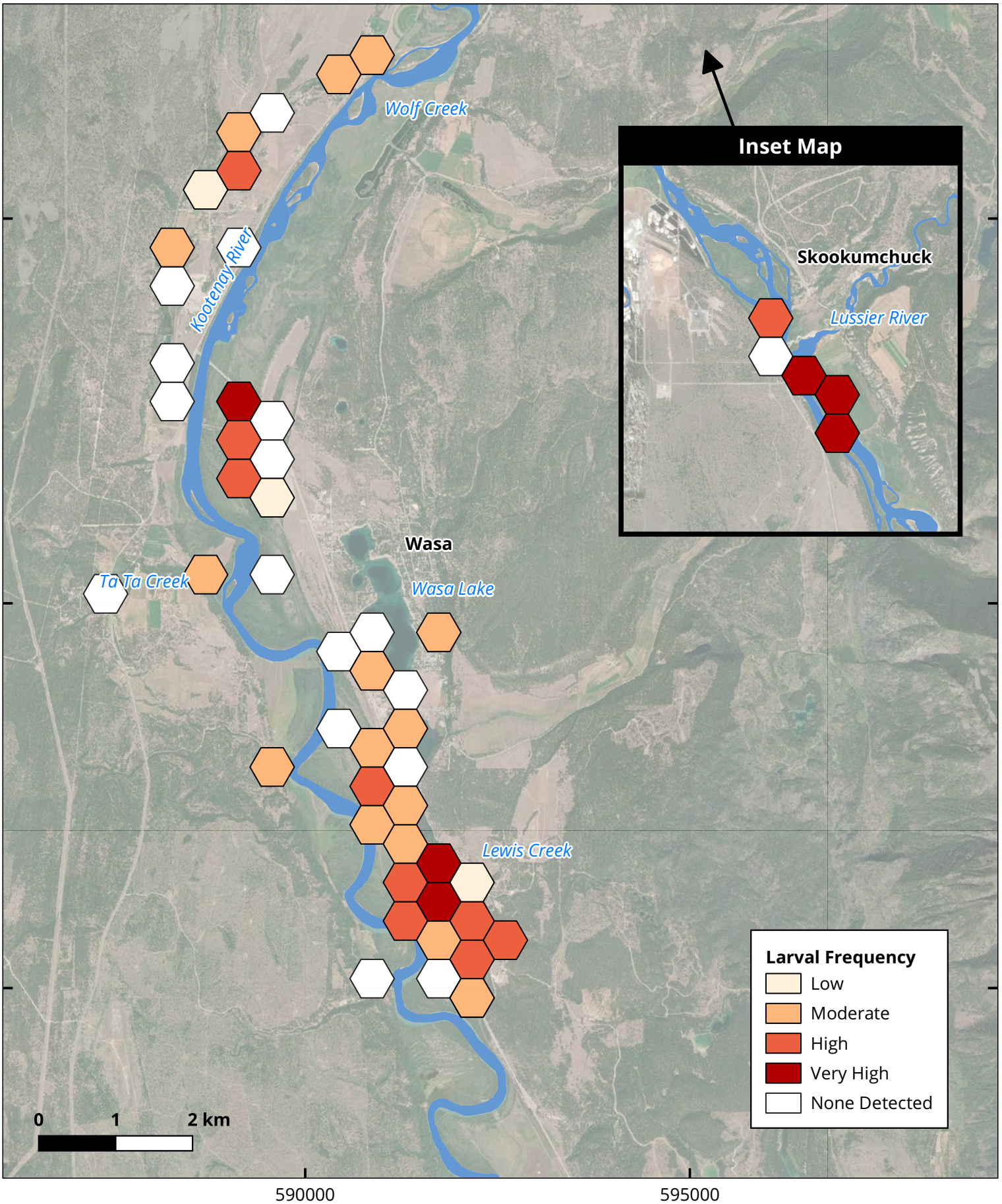
2021 Mosquito Larval Densities at Sample Locations

Appendix I

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

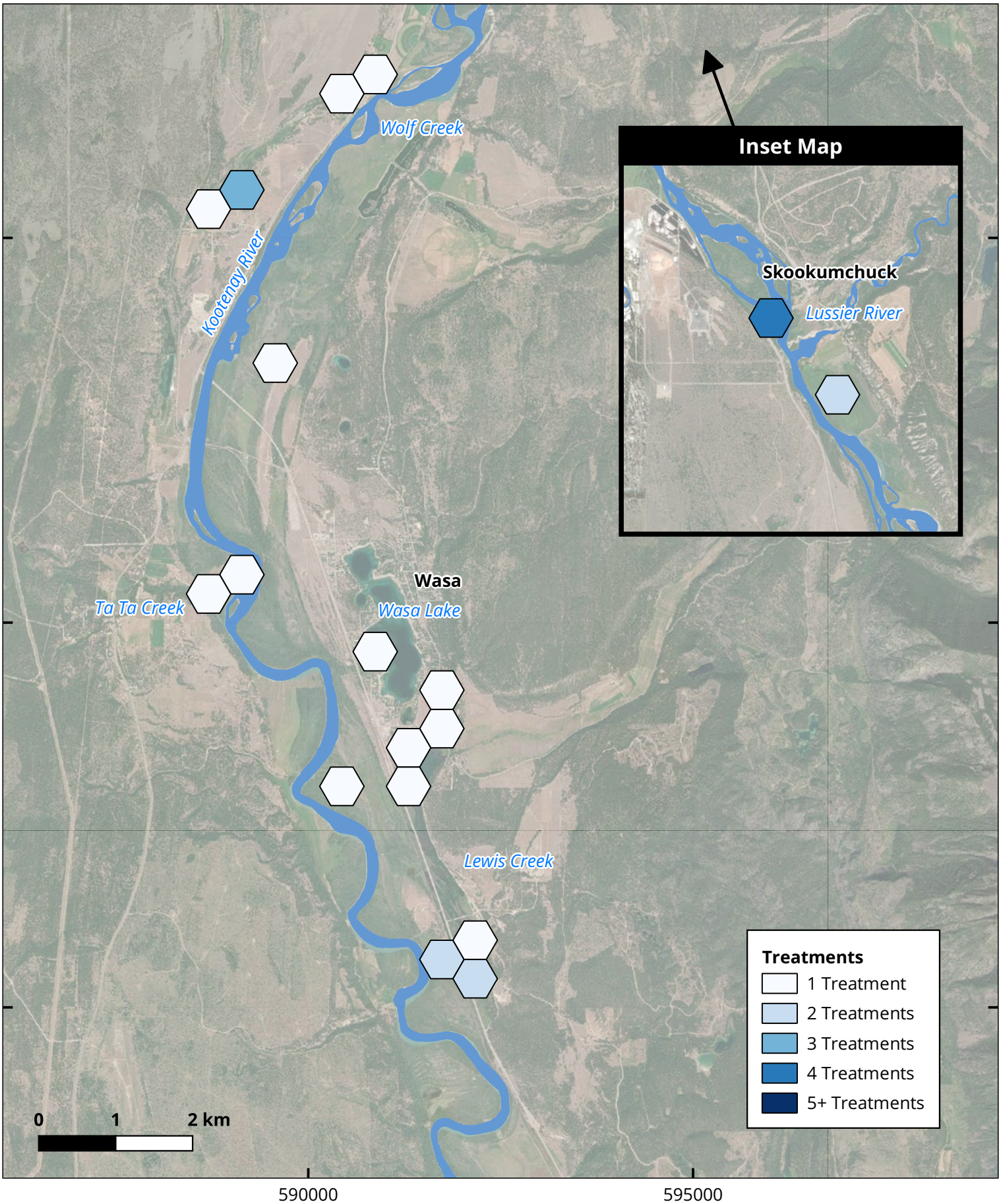


2021 Mosquito Larvicide Treatment Locations

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



Appendix III - 2021 Wasa/Ta Ta Creek/Skookumchuck mosquito larvicide treatment data (kg, ha) by site and date for all ground (A) and aerial (B) treatments

III-A: Ground Treatments

Treatment Date	Site Code	Site Name	Amount Treated (Kg)	Area Treated (Ha)
2021-05-27		Skoomkumchuck bridge	4.5	1.1
2021-05-27		Survey post hole	4.5	1.1
2021-06-01	RDEK-001	Praire Road	108.6	27.2
2021-06-01	RDEK-050	Bear Claw	91.0	22.8
2021-06-01	RDEK-008	South End Thunderhoof	9.0	2.3
2021-06-02	RDEK-050	Bear Claw	253.4	63.4
2021-06-12	RDEK-050	Bear Claw	16.4	4.1
2021-06-12	RDEK-048	Skookumchuck Bridge	12.0	3.0
2021-06-17		Trench between highway and railway thunderhoof	8.0	2.0
2021-06-17		Trench between highway and railway thunderhoof	4.0	1.0
2021-06-17		Trench between highway and railway thunderhoof	4.0	1.0
2021-06-18	RDEK-047	Muskrat ranch other side of road	54.0	13.5
2021-06-18	RDEK-027	Whites	36.0	9.0
2021-06-18	RDEK-042	Muskrat Ranch	26.0	6.5
2021-06-23	RDEK-042	Muskrat Ranch	36.4	9.1
2021-06-24	RDEK-045	Green Subdivision	8.0	2.0
2021-06-24	RDEK-018	Sawdust Pile	6.0	1.5
2021-07-07	RDEK-042	Muskrat Ranch	8.0	2.0
2021-07-07	RDEK-045	Green Subdivision	8.0	2.0

Appendix III - 2021 Wasa/Ta Ta Creek/Skookumchuck mosquito larvicide treatment data (kg, ha) by site and date for all ground (A) and aerial (B) treatments

III-B: Aerial Treatments

Treatment Date	Site Name	Amount Treated (Kg)	Area Treated (Ha)
2021-06-11	Program purview	2802.8	700.7
2021-06-12	Program purview	1783.6	445.9
2021-06-13	Program purview	2275.2	568.8