Regional District of East Kootenay
Wasa, Ta Ta Creek, Skookumchuck
Mosquito Control Program

2023 Year-End Report

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Executive Summary

Morrow BioScience Ltd. (MBL) has now completed the second year of a five-year contract term as mosquito control contractor for Wasa, Ta Ta Creek, and Skookumchuck within the Regional District of East Kootenay (RDEK). The mosquito control program reduces floodwater mosquito abundance within all areas of the project purview.

The snowpack in the East Kootenay Basin was lower-than-normal in April (81%), immediately preceding the mosquito monitoring season. The snowpack was slightly augmented in April, but warmer-than-average temperatures during May led to the prompt arrival of the Kootenay River freshet. Precipitation events during June may have amplified Kootenay River levels, but the river was already receding and below the critical levels needed to reactivate associated floodwater mosquito development sites. Warm ambient temperatures within the East Kootenay Basin persisted through mid-June, exhausting high-elevation snowpack by early in the month, resulting in peak Kootenay River levels on 18 May (3.758 m). The 2023 Kootenay River peak was lower than the 2022 peak due to lower snowpack in the East Kootenay Basin. The rapid melting period led to rapid water input to the regional river and also to the delivery of ground water to seepage sites. While there was a lack of compounded mosquito eggs triggered to hatch in 2023, water present at floodwater and seepage sites resulted in significant mosquito larval production.

Larval mosquitoes were treated between 13 May and 11 July. The total mosquito habitat treated by ground and air was 588 ha (2355 kg) in 2023. MBL treated 1754 ha less in 2023 than 2022 due to the shortly sustained high peak Kootenay River levels. No known sites were missed during ground-based or aerial treatment efforts. Just one aerial treatment was required in 2023, conducted on 25 May following the primary Kootenay River peak. At all known sites, 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.

No calls or emails were received from residents to the Mosquito Hotline in 2023. MBL staff respond to calls and emails within 24 hours of receipt. On 6 September, the BCCDC issued an Alert identifying one human case of West Nile virus in the Province as of September, suspected due to out-of-province travel. No reports of Zika virus have been identified to date. The 20 November report regarding the West Nile virus clarified that no cases originated from British Columbia as of that date.

Communications with program residents remains a priority for MBL. On May 30 MBL staff was interviewed on CBC. While not specific to the Wasa, Ta Ta Creek and Skookumchuck program, the interviews also provided advice specific to personal protective measures and mosquito habitat reduction tips. The reach of social media posts continues to increase annually, meaning that more residents around Wasa, Ta Ta Creek, and Skookumchuck may be aware of and engaged with mosquito abatement efforts.

Season Highlights

- The snowpack in the East Kootenay Basin was 81% of normal for 1 April, immediately preceding the floodwater mosquito season.
- ENSO-neutral (El Nino-Southern Oscillation) weather patterns slightly augmented the snowpack in the East Kootenay Basin through most of April.
- The freshet promptly arrived during May.
- The primary peak of the Kootenay River occurred on 18 May (3.758 m).
- The 2023 regional Kootenay River peak was approximately 0.39 m lower than the 2022 peak.
- Average precipitation was received to the region during May and April.
- Precipitation during June and July were both below average, while August was considerably above average.
- Due to lower Kootenay River levels and shortly sustained high water, lower larval abundance was observed in 2023, compared to 2022.
- One aerial campaign was required within the Wasa, Ta Ta Creek, and Skookumchuck mosquito program purview.
- Floodwater mosquito development sites associated with the regional Kootenay River were treated aerially on 25 May.
- Total area treated by air was 455 ha (1,820 kg granular Aquabac®).
- Total area treated by ground was 133 ha (535 kg granular Aquabac®).
- No complaint or inquiry calls or emails were received to the Mosquito Hotline in 2023 as of 1 September.
- MBL staff gave one interview to CBC provincial media. Information pertaining to personal protection and habitat reduction was relevant to Wasa, Ta Ta Creek, and Skookumchuck residents.
- The BCCDC issued an alert (6 September) identifying one case of West Nile virus in the province suspected to have originated due to out-of-province travel. The 20 November report updated this information confirming no WNv cases originated from the province to date.
- Relatively low levels of WNv activity were reported in Washington State and Idaho State despite a warmer-than-normal spring and early summer.
- Recommendations for the 2024 season include engagement with the Nature Trust regarding options for floodwater mosquito reduction within Bummers Flats, possibly revising RDEK Pest Management Plan to include the use of RPAS (Remotely Piloted Aircraft System – a.k.a “Drones”) for larval treatments, updating and distributing door knockers, and potentially developing an RDEK-hosted project page on the RDEK website.

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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, and Skookumchuck area within the Regional District of East Kootenay (RDEK) since 1997. In 2023, MBL started the second year of a five (5) year contract to provide mosquito control to the residents of Wasa, Ta Ta Creek, and Skookumchuck.

The extensive mosquito habitat, program reach, and inter-annual regional river variations make the Wasa, Ta Ta Creek, and Skookumchuck mosquito control program complex. However, throughout MBL's contract tenure with this program, MBL staff has acquired thorough knowledge of the area and how region-specific environmental conditions affect mosquito development sites. In addition to having built a program knowledge base, numerous improvements have been made to the program since its inception, including:

- comprehensive site survey of seepage sites associated with Kootenay River,
- identification of new mosquito development sites,
- the addition of a real-time data collection and review portal,
- increased public engagement through social media, radio and in-person events,
- improved environmental awareness of program impacts through annual carbon offset purchases.

MBL's goal is to continue to provide effective mosquito control to the Wasa, Ta Ta Creek, and Skookumchuck residents, while remaining socially and environmentally responsible.

Carbon Offsets

The spatial reach of the Wasa, Ta Ta Creek, and Skookumchuck mosquito program is such that driving is an inevitable requirement. As an organization, MBL travelled just under 100,000 km. The accumulated mileage for the RDEK program over the course of 2023 was approximately 3,600 km (ground transportation only). As an estimate, the driving requirements for this program resulted in the production of approximately 0.9 tonnes of CO_2 emissions.

To offset this addition of CO_2 to the environment, MBL has committed to purchasing carbon offsets. To fulfill this commitment, carbon offsets are purchased through the Neighbours United – formerly 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 program manager.

MBL has chosen to support Neighbours United due to their work with communities to educate residents, and support the advancement of clean, renewable energy transitions and nature-based solutions and policies across BC and Canada.

[1] https://neighboursunited.org

Methodology

As large areas of the Wasa, Ta Ta Creek, and Skookumchuck purview are within the Kootenay River flood plain, the primary targets of the mosquito control program are floodwater mosquito larvae. Female floodwater mosquitoes (e.g., *Aedes vexans*, *Ae. sticticus*) deposit their eggs on damp substrate that experiences flooding. Within Wasa, Ta Ta Creek, and 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 precipitation, the result is large-scale floodwater mosquito egg hatching. If more than one season has passed between high-water years, then high river levels may trigger a compounded number of mosquito eggs to hatch, resulting in a compounded 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 environmental hatching cues.

MBL field technicians begin monitoring all known mosquito development sites within Wasa, Ta Ta Creek, and Skookumchuck as the Kootenay River levels start consistently rising in the spring months. Mosquito development sites are adaptively managed, meaning that the regional river levels and environmental conditions largely dictate frequency of visits, as opposed to a prescribed monitoring schedule.

At the height of the mosquito season, MBL staff may monitor highly productive sites multiple times a week. Adaptive management techniques allow MBL staff to most accurately time treatments, if necessary. Prescribed monitoring methods increase the risk of missing optimal treatment windows due to accelerated mosquito development rates with rising temperatures (Read and Moon 1996). Hence, as regional river levels and ambient temperatures begin to rise consistently, monitoring efforts increase.

Image 1. Standard dip (350 ml) with 3rd and 4th instar floodwater mosquito larvae.

Larval mosquitoes in sufficient number (i.e., >4/dip; Image 1) are treated by applications of a microbial larvicide product, Aquabac®. This product has the active ingredient *Bacillus thuringiensis* var. *israelensis* (Bti). In 2023, only the granular formulations of Aquabac® was used, which is carried on a corncob mixture. The mode of action is relatively simple and with a high degree of target species specificity. Receptors within the mid-gut region of the mosquito larvae are compatible with 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 damage to the wall of the gut and quickly leads to larval death (Boisvert and Boisvert 2000).

As the season progresses and more mosquito development sites become flooded, it is increasingly difficult to treat sites 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 typically with a higher application rate to permeate canopy cover. All sites are checked within 1 or 2 days of the initial treatment to ensure treatment efficacy. If necessary, touch-up treatments are conducted.

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 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 4th instar stages, early instar larvae are available as food sources within the ecosystem. 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).

Environmental Conditions

The three primary environmental conditions that affect floodwater mosquito larval production throughout the mosquito season (i.e., April – August) within Wasa, Ta Ta Creek, and Skookumchuck are: 1) the snowpack in the East Kootenay Basin, 2) local precipitation, and 3) local ambient temperature and ambient temperature within the East Kootenay Basin. Each condition provides insights regarding floodwater mosquito egg

hatching onset, development rate, and success. As such, all noted conditions are tracked throughout the season.

Snowpack

Floodwater mosquito abundance within Wasa, Ta Ta Creek, and Skookumchuck is largely governed by regional Kootenay River water levels (Fort Steele gauge – ID: 08NG065). The water levels of that system are governed by the snowmelt released primarily from the East Kootenay Basin. When snowpack within the East Kootenay Basin exceeds 100 percent of normal, higher-than-average Kootenay River levels are expected during the mosquito season. Similarly, high ambient temperatures within the East Kootenay basin can compress the melt timeline, resulting in high regional river levels even if the snowpack in those basins does not exceed 100 percent.

On 1 April, immediately preceding the 2023 Wasa, Ta Ta Creek, and Skookumchuck mosquito monitoring season, the snowpack within the East Kootenay Basin was 81 percent of normal. The lower-than-normal snowpack was likely a result of the ENSO-neutral weather pattern that was in place during the spring of 2023. The 2023 snowpack heading into the mosquito season was lower than that of 2022. A high pressure weather pattern took hold in British Columbia during May, with warm weather within the East Kootenay Basin through mid-June resulting in the rapid depletion of high elevation snowpack. These circumstances led to the rapid arrival of freshet.

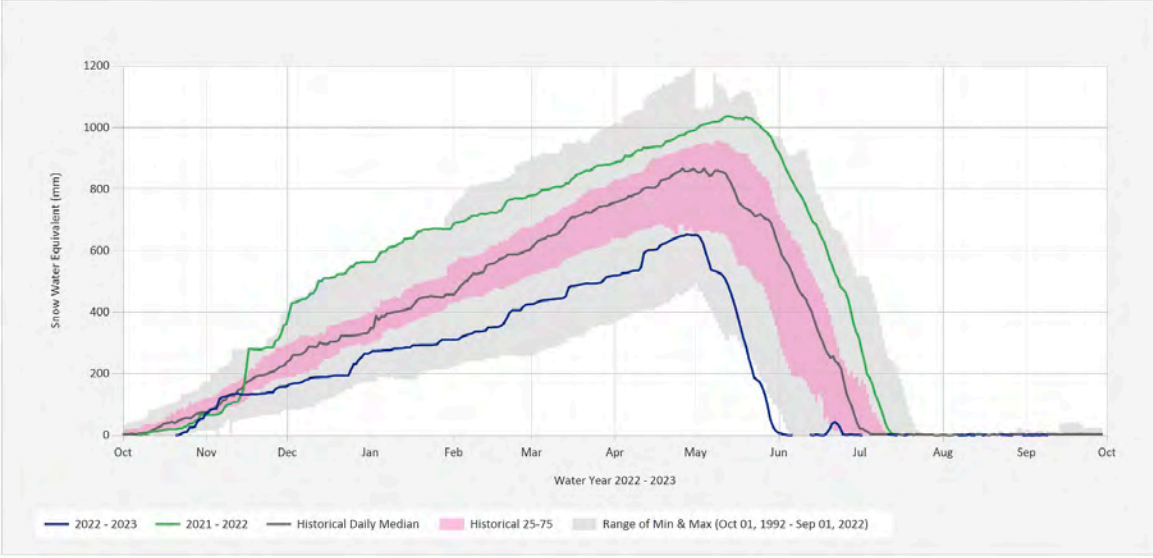

Figure 1 Snow Water Equivalent (SWE; mm) data from the Floe Lake snow survey (station ID: 2C14P) within the East Kootenay Basin (2023 blue line). (2022 snow levels shown in green.)

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. Over-all, the Snow Survey data show the Snow Water Equivalent (SWE) was below average for this station in 2023; low SWE was recorded from December 2022 – July 2023 (Figure 1). A brief melting stint occurred in mid-April[2]. Snow station data also show the first measurable

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

melting trend in mid-May, with the lower and middle-elevation SWE dropping significantly.

In normal years, by 15 June most of the snowpack has melted within the East Kootenay Basin. However, with warming ambient temperatures in the East Kootenay Basin during May, snowpack was depleted early-June. The 1 June snow basin index for the East Kootenay Basin was 1 percent of normal[4]. Warming weather caused the consistent reduction in SWE at the Floe Lake snow survey station until early-June, when the snowpack at this survey station was depleted (Figure 1). Other snow survey stations throughout the East Kootenay Basin show similar trends[3]. Thus, by mid-June any fluctuations in the regional Kootenay River levels were likely not due to regional snowmelt contributions.

Generally, the snowpack remained within the East Kootenay Basin for approximately one month shorter than normal. The late-season input of water to the Kootenay River was minimal, reflecting the relatively low intensity of adult mosquitos within Wasa, Ta Ta Creek, and Skookumchuck. The 2023 Kootenay River freshet was set apart by the low snowpack and rapid snowmelt from the East Kootenay Basin. These features led to early and shortly sustained Kootenay River levels into late May, when increased mosquito egg hatching cues were more abundant within the program purview.

Local Precipitation

Substantial temporally and spatially concentrated precipitation accumulation may elevate regional Kootenay River levels and increase seepage site levels. Local precipitation can also temporarily create micro-mosquito development sites (e.g., hoof prints, car tracks) where container 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, regional river and seepage site levels may be higher or sustained for longer. Both scenarios may lead to additional floodwater mosquito egg hatches.

The precipitation received to the Cranbrook Airport weather station in April (26.2mm) was close to the monthly station average (1981-2010; Figure 2). Thus, it is likely the precipitation received locally slightly impacted Kootenay River levels and associated seepage sites in April. Near average precipitation was received to the region during May and below average precipitation during June and July. It is possible that this specific precipitation events during May slightly augmented river levels above those that would

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

have been observed due to the freshet alone and may have contributed towards the recorded peak of the regional Kootenay River.

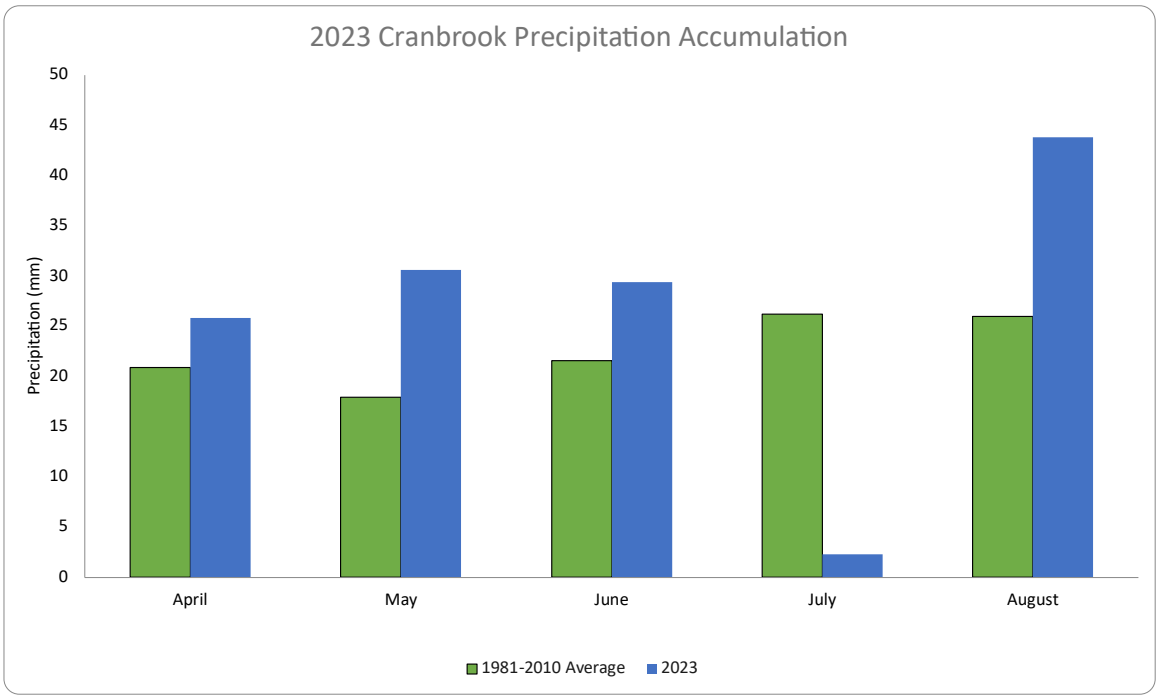

Figure 2 Precipitation values (rainfall and snow accumulation; mm) recorded at the Cranbrook Airport Auto weather station (ID: 1173220) for 01 April – 31 August 2023 (blue) and average station precipitation values (1981-2010; green).

Precipitation increased during August at a time when region water levels were low (Figure 2). Regional precipitation received during June, July and August was of little consequence to the Kootenay River, as regional levels were receding due to the lack of snowmelt input. It's possible that precipitation received during those months created habitat for container mosquito species to reproduce. Thus, adult mosquito presence toward the end of the season was likely due to container mosquitoes dispersing from these sites, including hoof prints and tire tracks, and not floodwater mosquito species in certain areas.

Ambient Temperatures

Local ambient temperature and ambient temperature within the East Kootenay Basin are important variables to track. Local ambient temperature fluctuations from April through August can affect mosquito egg hatching, larval development rates, adult dispersal, and adult survival within Wasa, Ta Ta Creek, and Skookumchuck mosquito development habitat. Within the East Kootenay Basin, ambient temperature dictates the commencement and often the intensity of the freshet, which directly impacts floodwater mosquito development habitat.

East Kootenay Basin Temperatures

The 2023 mosquito monitoring season began in April with slightly below-average ambient temperatures within the East Kootenay Basin. The generally cool weather in April was interrupted by a high pressure system that took hold across much of the province in late April[4], with ambient temperatures ranging from +1.1 to +5.1°C above average during May[5].

The high-pressure system that began at the end of April resulted in very warm temperatures which rapidly reduced contributing snowpack. The first significant spike in ambient temperature occurred in late-April[6]. The spike prompted middle and high-elevation snowmelt within the East Kootenay Basin and the rapid rise of regional Kootenay River levels. Following the spike in ambient temperature, warm weather continued through July. The continued warm ambient temperatures led to the early exhaustion of high-elevation snowpack by early June. Coupled with local precipitation, this rapid release of freshet was sufficient to provide a relatively high regional peak in the regional Kootenay River during late May, despite lower-than-average snowpack present as of 1 April. (see 'River Levels ' below).

Ambient temperatures continued to rise through July and August. However, after the depletion of the East Kootenay Basin snowpack, ambient temperatures within that basin do not typically impact floodwater mosquito habitat within the program purview. Ambient temperature data are consistent with 2023 automated snow station data depicting snowmelt points correlating with regional ambient temperature spikes[7].

Wasa, Ta Ta Creek, and Skookumchuck Ambient Temperatures

Local ambient temperature is a predictive tool when gauging floodwater egg hatch commencement. 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). Local ambient temperature data are acquired from the Cranbrook Airport Auto weather station (ID: 1152106).

To illustrate the effect of ambient temperature on floodwater mosquito egg hatching events, Trpis and Horsfall (1969) exposed submerged eggs of a common univoltine floodwater mosquito species, *Aedes sticticus*, to various constant air temperatures and recorded hatching success. Results revealed that eggs began to hatch at 8°C, although larval development was slow, and survivorship was low. Eggs held at 21°C provided the optimal temperature, of the five temperatures tested, for hatching and larval development (Figure 3). While *Ae. sticticus* is not the sole floodwater species present in Wasa, Ta Ta Creek, and

[4] 2023.pdf (gov.bc.ca)
[5] *Id.*
[6] *Id.*
[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

Skookumchuck, it serves as a representative species for our purposes and provides general developmental benchmarks.

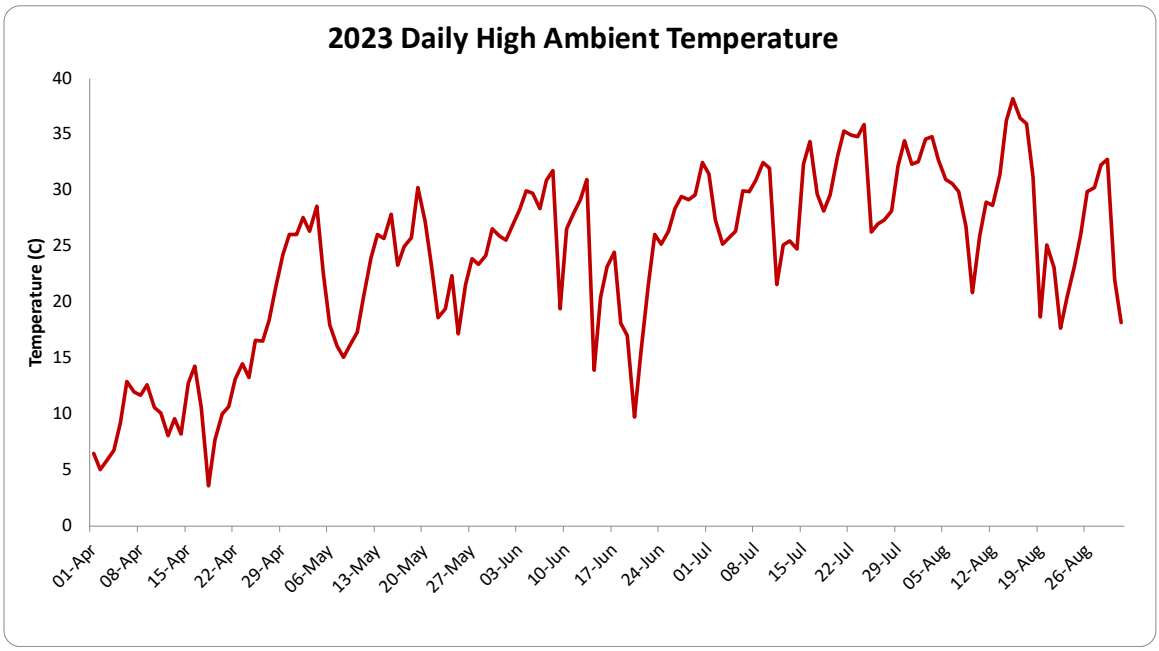

Figure 3. Maximum daily ambient temperatures (C) as recorded at the Cranbrook Airport Auto weather station (ID: 1152106) 01 April – 31 August 2023.

Within the Wasa, Ta Ta Creek, and Skookumchuck purview, the 2023 season began with cool ambient temperatures for April. The 2023 monthly average for April was 11.8 °C. Given that monthly temperatures were frequently above the lower temperature bound for successful *Ae. sticticus* mosquito egg hatching, floodwater mosquito eggs within Wasa, Ta Ta Creek and Skookumchuck would have been likely triggered to hatch within April if exposed to flooding conditions that were not present during April of 2023 (Figure 3).

Local ambient temperatures in May were much warmer and within the temperature range for favourable floodwater larval development of target mosquito species (Figure 3). The average maximum daily temperature for May was approximately 23.3°C. Thus, floodwater mosquito egg hatching and larval development rates increased within May.

Ambient temperatures in June were higher than May temperatures and provided sufficient hatching cues for floodwater mosquito eggs exposed to water. The average daily maximum temperature in June was 25.2°C. Although local ambient temperatures were warmer than average in June, the reduction of regional Kootenay River levels, reduced the duration of flood water mosquito larvae hatching events later in the month. Therefore, because considerable floodwater development sites were at low levels from mid-June through early-July, the need to treat mosquito larvae during those times was directly associated with ambient temperature.

As predicted by the Temperature and Precipitation Probabilistic Forecasts for Canada, July and August ambient temperatures were higher than average. Because the freshet was

slightly early, there was minimal floodwater mosquito habitat and activity through July. High ambient temperatures, such as those noted in later July and August, decrease the lifecycle of adult mosquitoes (Ciota et al. 2014). Thus, any mosquitoes that successfully emerged would have had a reduced lifespan with the heightened ambient temperatures into late August (Figure 3).

While not a target of the Wasa, Ta Ta Creek, and Skookumchuck mosquito control program, container mosquito abundance typically increases in July and August. Container mosquito habitats near residential homes can be created throughout warmer summer months whenever the presence of water is coupled with high ambient temperatures. MBL technicians regularly inform residents that container-bred mosquitoes can be reduced around homes by ensuring conducive environments (i.e., bird baths, kiddy pools, flowerpot holders, etc.) are either free of water or refreshed frequently.

River Levels

Floodwater mosquito development sites within Wasa, Ta Ta Creek, and Skookumchuck are found along the 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.

From late-April through mid-June, unseasonably warm temperatures brought the annual Kootenay River freshets earlier than average. (Figure 4). The freshet was present until the Kootenay River peaked on 18 May, followed by a measurable decline in water levels until mid-June. The river level increases that began in late April marked the rapid and consistent rise of the regional Kootenay River in 2023. Floodwater mosquito eggs laid on substrates at various river levels have optimal environmental cues and adequate time within which to hatch when rivers rise at a slower rate. When river levels rise at high rates, mosquito eggs typically lack sufficient environmental cues due to the pulse of cold, highly oxygenated water moving through the system. The regional Kootenay River rose at a rapid rate in 2023 but was sustained long enough to present environmental cues needed to trigger a substantial mosquito hatching event.

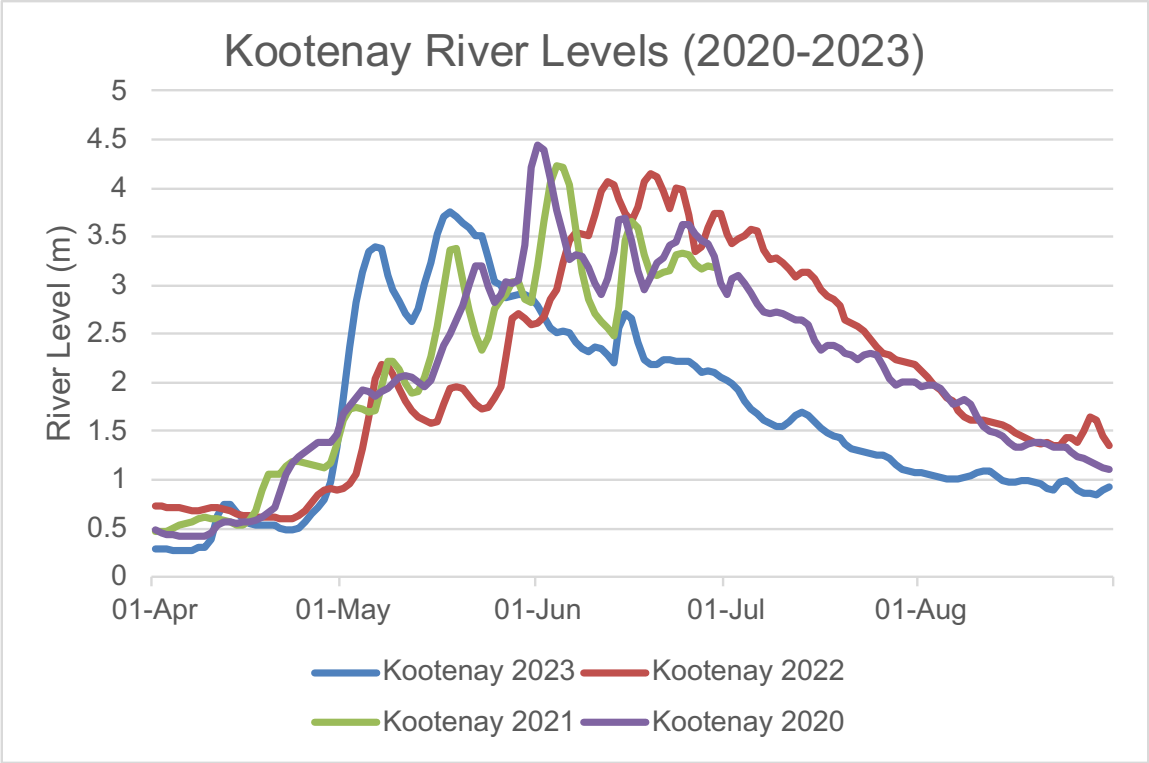

Figure 3 2020-2023 Kootenay River levels (m) as recorded at the Fort Steele gauge (08NG065) from 1 April – 31 August.

The provincial warming trend continued into June and July but had little effect on the Kootenay river as snowpack was already exhausted (Figure 4). As a result of the early warming trend, the peak in the Kootenay River was recorded on 18 May (3.758 m). The peak provided hatching cues for floodwater mosquito eggs and required large-scale treatments. The depletion in snowpack corresponded with a marked decline in the regional Kootenay River levels (Figure 3). When the regional Kootenay River levels consistently remain below 2 m, associated seepage sites reduce quickly. Thus, by late-June many of the mosquito development sites were becoming dry.

The current year's peak in the regional Kootenay River relative to that of the recent season's is another predictive variable that may help explain a current year's larval abundance. If the current year's peak river levels far exceed that of the preceding season's, mosquito eggs laid between the high-water mark of both years could remain dormant until current-year flood waters trigger their hatching. The 2023 Kootenay River peak was approximately 0.39 m lower than the 2022 peak (Figure 3). Although regional snowpack was much lower in 2023 than in 2022, with the rapid snowmelt of 2023 resulted in a relatively high but short-lived peak of regional rivers. The peak of the Kootenay River in 2023 was lower than that of 2022 and did not trigger a compounded number of floodwater mosquito eggs to hatch. Seepage sites are ideal floodwater mosquito habitat and, thus, required less treatments in 2023 in comparison to 2022, due to reduced peak levels and duration of high water.

Larval Control

Floodwater mosquito monitoring begins when spring ambient temperatures start to rise steadily in the East Kootenay Basin, followed by consistently increasing regional Kootenay River levels. Consequently, floodwater mosquito development site monitoring began on 4 May. Although most of the floodwater mosquito development sites usually are not active until the regional Kootenay River rises late in May, sites were monitored beginning in early-May to evaluate site conditions and respond to the early arrival of freshet. Warm ambient temperatures coincided with increased floodwater mosquito development site monitoring and larval mosquito treatments during May.

Appendix I shows a map of average larval densities found throughout the 2023 season. Larval abundance is assessed in the field using a system of ranges (0, 1-4, 5-49, 50+) for early and late instar mosquito larvae. In order to transfer these data to a map (Appendix I), data are summarized and assigned to a hexbin (i.e., polygon) 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 mosquito larvae are assigned to each single sample. For each sample, late instar larvae ranges are weighted more heavily than early instar larvae ranges to indicate targeted life stage and treatment urgency. In this way, each sample is assigned an intensity value from 0 to 1. All sample intensity values are then averaged by hexbin. Thus, each hexbin is also assigned an average intensity value from 0-1. The intensity value thresholds within **Appendix I** denoting 'low', 'moderate', 'high', and 'very high 'were assigned based on biological significance and operational urgency. Of note, the areas with highest recorded larval abundance amongst known sites were within Skookumchuck near the confluence of the Lussier River and Kootenay River, along Skookumchuck Rd., the break-aways of Wasa Lake, and south of Wasa at seepage sites along the Kootenay River. No new mosquito development sites were identified throughout the Wasa, Ta Ta Creek, and Skookumchuck program purview in 2023.

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 neighbouring hexbin; each of these circumstances may create skewed results.

A total of approximately 588 ha (2355 kg was treated within Wasa, Ta Ta Creek, and Skookumchuck in 2023. For comparison, MBL treated 1754 ha less in 2023 than in 2022. Although 2023 could be considered a high water year, the Kootenay River levels were sustained for a shorter period of time in 2023, with seepage sites drying earlier due to receding groundwater. No known sites were missed in ground-based or aerial treatment efforts.

Appendix II is a map depicting where and how frequently treatments took place in 2023. 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. 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. However, maps provide a high-level understanding of where treatments were concentrated.

Ground Application Summary

Mosquito development sites within Wasa, Ta Ta Creek, and Skookumchuck are visited on a weekly basis unless conditions required more frequent monitoring (i.e., Kootenay River levels > 3m, ambient temperatures > 20°C, large precipitation event). Sites are treated when a standard dip (350ml) collects 5 or more late instar (3^{rd} or 4^{th} instar) larvae per dip. All sites are checked within two days of the initial treatment to ensure high treatment efficacy. If necessary, touch-up treatments are conducted.

Aquabac® (a.i., *Bacillus thuringiensis* var. *israelensis* (BTI)) is the product used for all larval mosquito treatments conducted by MBL. Bti has high target specificity and achieves 95% - 100% efficacy in typical field conditions (Aquabac® Mosquito Biolarvicide - Technical Bulletin). Within Wasa, Ta Ta Creek, and Skookumchuck's highly organic floodwater mosquito site conditions, MBL staff note an average field efficacy rate of approximately 85%-90%. The granular formulation was used in 2023. The majority of mosquito development sites within Wasa, Ta Ta Creek, and Skookumchuck require 4 kg/ha when treated by ground.

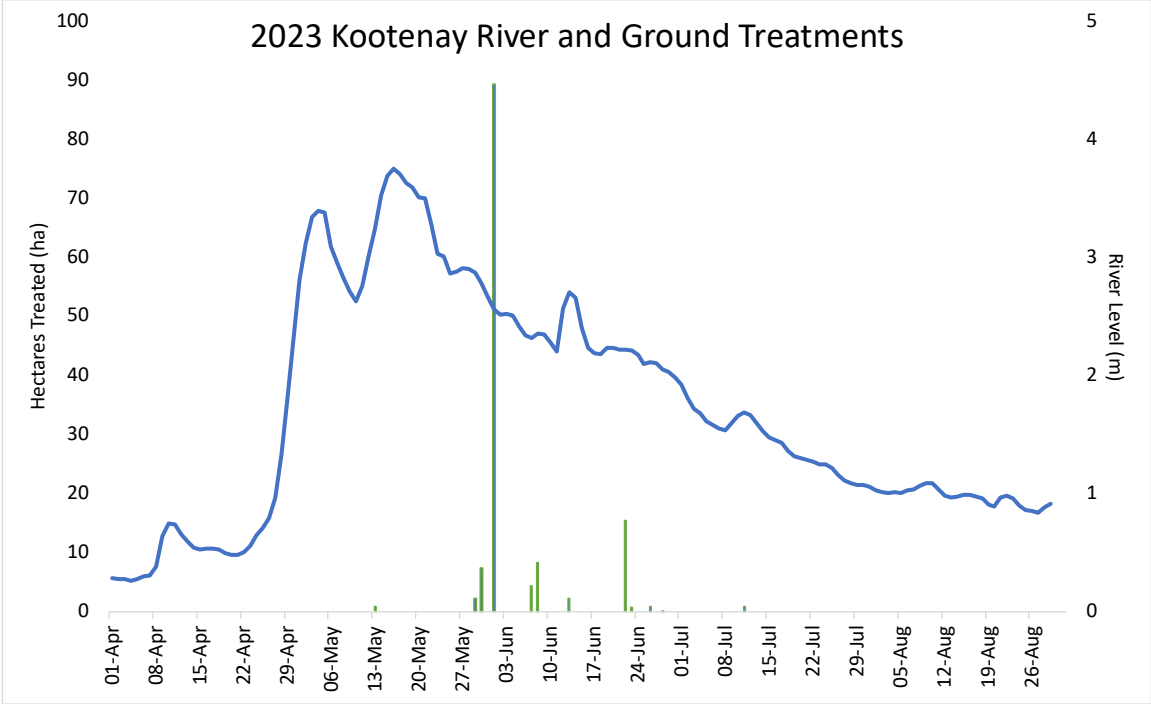

Figure 4 Kootenay River levels (m; Fort Steele gauge) with total mosquito development area treated by ground (ha) from 1 April – 31 August 2023. Note River levels (m) are recorded on the alternate y-axis.

The first ground treatment occurred on 13 May and continued through 11 July (Figure 4). Treatments began prior to the Kootenay River peak and through the peak. The total area treated by ground in 2023 was approximately 133 ha (535 Kg Aquabac®; 4 kg/ha) (Figures 4, 5). With river levels being sustained for a shorter period of time in 2023, a reduced amount of treatments were required. Real-time data associated with each treatment are available through MBL's client-registered, real-time program portal.

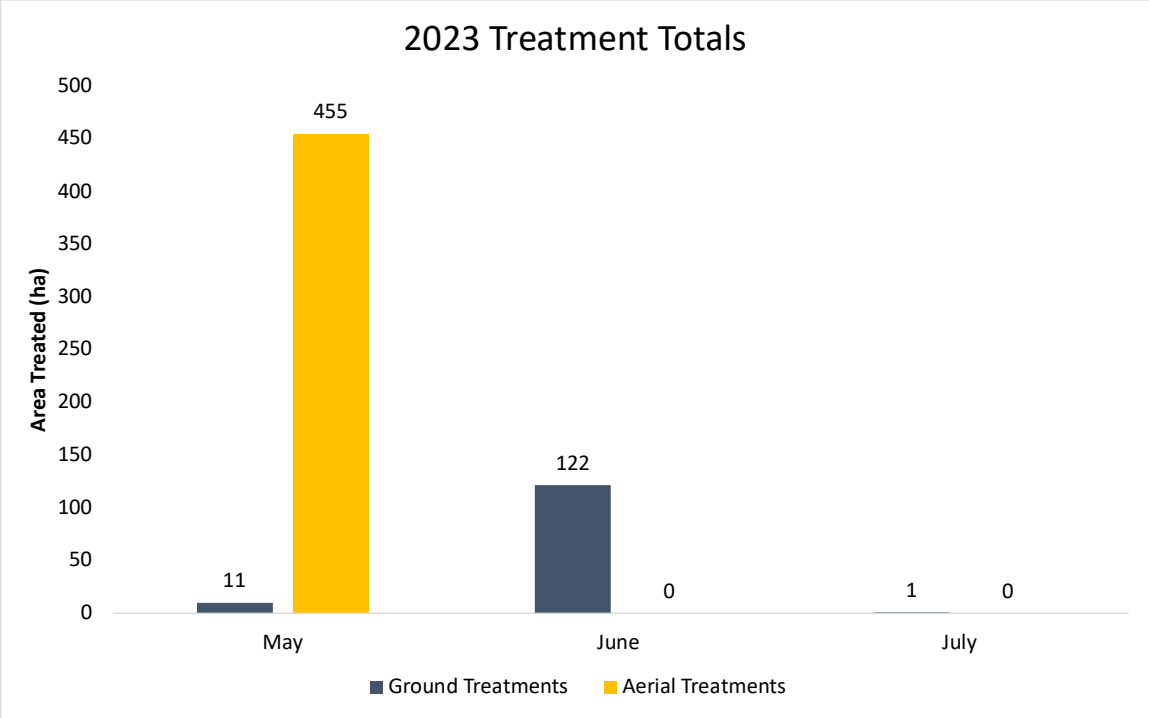

Figure 5 2023 ground-treated and aerially-treated area (ha) by month from April – July.

Aerial Application Summary

Floodwater mosquito development sites are treated by air when multiple large-scale sites become active at once and/or when site-access by ground is unsafe. One aerial campaign was required within Wasa, Ta Ta Creek, and Skookumchuck in 2023. The aerial campaign took place on 25 May (Figures 5, 6). For comparison, far less hectares were treated in 2023 aerial campaigns than in 2022. The difference in total area treated in aerial campaigns signifies the shortly sustained high-water levels in 2023 in comparison to the more persistent peak levels of 2022.

Aerial treatments were conducted using granular Aquabac®. Aerial treatments were applied at an average rate of 4 kg/ha. A total of 455 ha was treated by air, equating to a total of approximately 1,820 kg of Aquabac® used. Figure 7 shows the aerial treatment events (orange) with Kootenay River (Fort Steele gauge) levels. **Appendix II** includes all treatments within each hexbin (i.e., polygons).

Aerial treatment events typically take place immediately after the Kootenay River at Fort Steele has peaked because the Bti is able to reach mosquito larvae before they disperse with rising water. As it is difficult to determine exactly when the peak will occur, aerial treatments often bookend a peak. Additionally, when the Kootenay River is sustained at high water levels, more floodwater mosquito eggs may have time and abundant environmental cues to hatch. Aerial treatments were conducted immediately following the primary Kootenay River peaks (18 May; Figure 7). In this way, the aerial treatment timing in 2023 was ideal. MBL staff were able to accompany the helicopter pilot again in 2023, which aids in identification and treatment of inconspicuous mosquito development areas.

The treatment successfully controlled targeted floodwater mosquito larvae. **Appendix III** shows more specific information about site, treatment timing, and extent of treatment.

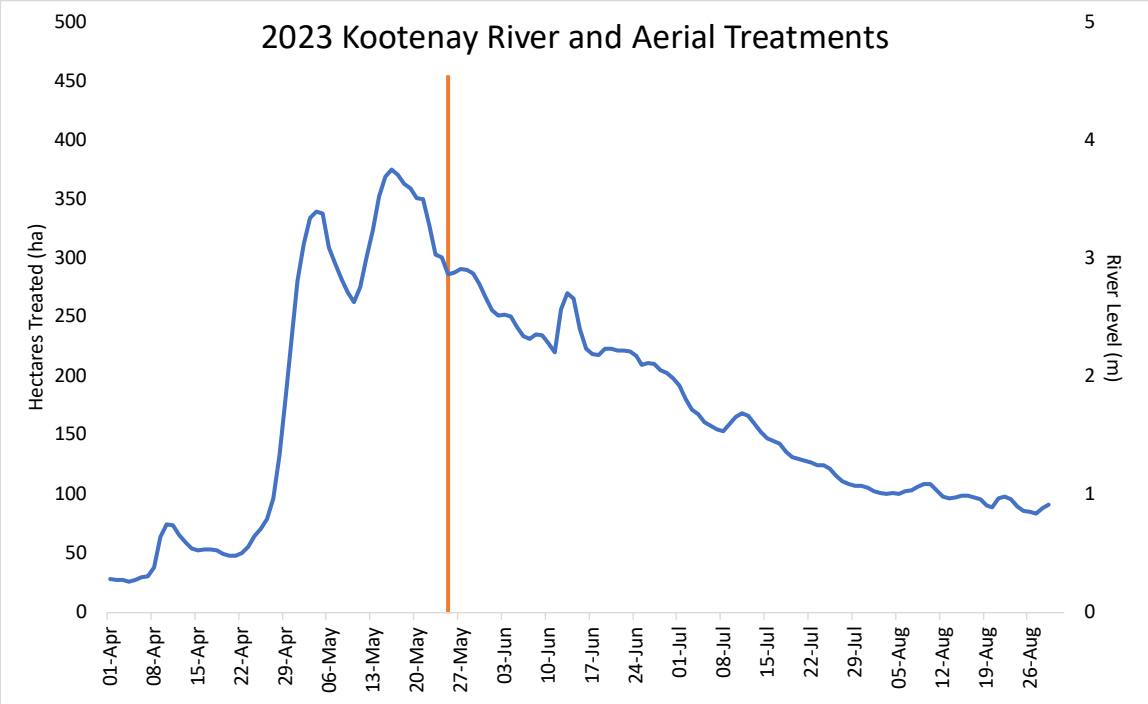

Figure 6 Kootenay River levels (m; Fort Steele gauge) with total mosquito development area treated aerially (ha) from 1 April – 31 August 2023. Note River levels (m) are recorded on the alternate y-axis.

Public Engagement

Maintaining positive communication with the public continues to be a high priority for MBL. Public engagement occurs on several levels: in-person communication with members of the public, the mosquito hotline, presentations to stake holders, email correspondence, and 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, and Skookumchuck residents have multiple venues to communicate with MBL. MBL's Mosquito Hotline (877-986-3363) and email form are outlined prominently on the contact tab of the MBL website (www.morrowbioscience.com). The RDEK has also established a mosquito control website with contact information, FAQ links, and report links[8]. Emails and calls received to the RDEK program manager are documented and forwarded to MBL staff for follow-up.

There were no emails received by the RDEK program manager and passed along to MBL staff in 2023. No calls were received to the MBL mosquito hotline from Wasa, Ta Ta Creek,

[8] https://www.rdek.bc.ca/departments/environmentalservices/mosquito_control/

or Skookumchuck residents. MBL's goal is to return all concern calls and emails within 24 hours. The total number of calls and emails received in 2023 was lower than those received in 2022. In higher water years, the untreated Bummers Flats area becomes a significant mosquito development site. Floodwater mosquitoes that disperse from this site impact residents in Wasa, Ta Ta Creek, and Skookumchuck.

MBL remains committed to continuing reconnaissance efforts to identify floodwater mosquito development sites, adaptive site management, and expanding in-house knowledge of sites. Expanding public engagement reach may also result in the identification of new sites and reduction of mosquito larvae in the region. Through these efforts, MBL aims to further reduce adult mosquito nuisance within the Wasa, Ta Ta Creek, and Skookumchuck mosquito control purview.

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 residents. These encounters provide an excellent opportunity for public relations. An important outcome of these interactions can be the identification of new sites.

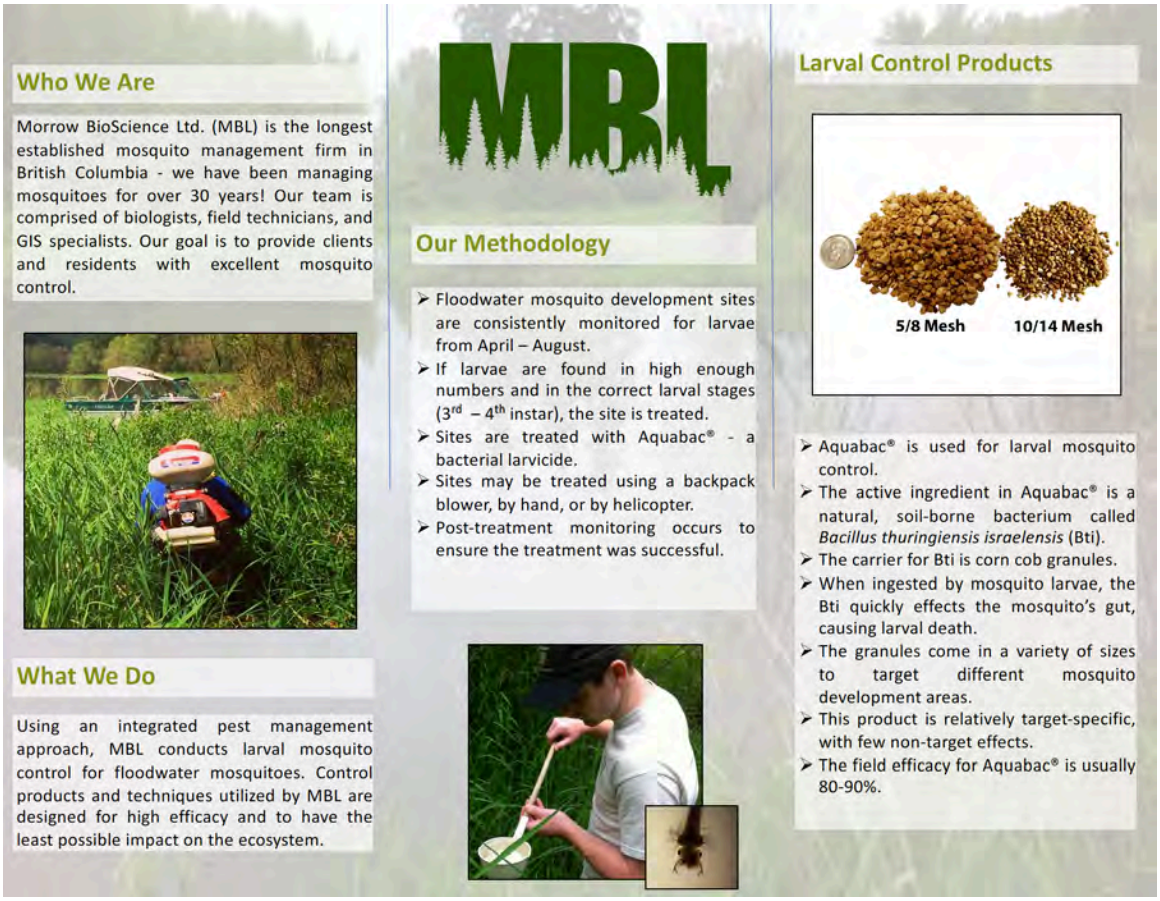

Image 2. MBL education outreach pamphlet.

MBL contact information is disseminated when field technicians have direct communication with the public. Contact information for MBL includes the website address, email address, phone number, and social media sites (Twitter, Facebook, Instagram). 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.

Online Engagement

MBL maintains a presence on social media with a Facebook account (facebook.com/morrowbioscience) and Instagram account (morrowbioscience), which are regularly updated. We no longer maintain an X (formerly Twitter) presence. 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.

Image 3. Facebook post showing an aerial treatment taking place at mosquito development sites near Wasa (17 June 2022)

Facebook and Instagram remain the primary avenues for MBL to disseminate mosquito-related information on social media. Periodic updates on mosquito activities began in early April. The total number of followers on the MBL Facebook page was 387 as of 26 November and the total number of followers on Instagram was 154.

Another way to determine how many people are engaging with MBL's posts is by considering MBL's post 'reach'. In 2023, the total reach pertaining to the RDEK mosquito control program was 178 (Facebook) and 76 (Instagram). The relatively low reach of posts this year likely reflected the lower-than-average abundance of adult mosquitoes. All posts related to the RDEK mosquito program included the hashtag: #rdekmosquitoes.

The MBL website also contains opportunities for public engagement. 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 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. homepage (www.morrowbioscience.com)

The website specifically highlights two sets of FAQs focused on (1) mosquito biology and disease transmission, and (2) the active ingredient used in control efforts (*Bacillus thuringiensis* var. *israelensis*). MBL has added new blogs discussing relevant education outreach topics. Information dedicated specifically to mosquitoes and COVID-19 (published in May 2020) remains available on the website.

Education Outreach

MBL staff was interviewed by CBC news (30 May 2023) and provided detailed information regarding its integrated pest management methodology and strategies used for the assessment of environmental conditions and larval treatment of floodwater mosquitoes in light of the historic flooding and subsequent mosquito infestation of 2022 to the lower Mainland (specifically in the Fort Langley area). MBL posted the article on its website. (2 June).

While this interview was requested on behalf of mosquito control programs run by MBL on the coast, the interview included tips for residents to reduce mosquito habitat around homes and how to increase personal protective measures. These recommendations are applicable to all program residents. If opportunities arise, MBL staff ensure that the RDEK mosquito program manager is consulted prior to agreeing to an interview. Every effort will be made to accommodate interviews which assist in raising awareness about mosquito control efforts and personal protective measures.

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 20 November, no human cases of WNv were reported to Health Canada originating from British Columbia[9]. An Alert issued on 6 September, 2023, identified one human case, however, it is suspected that the source was otherwise identified (e.g. out of province travel.)[10]. No horse or bird cases were reported from British Columbia within 2023. The most recent situation update published by the Public Health Agency of Canada, which includes data up to 5 August, 2023, reported no mosquito pool evidence of WNv from British Columbia. *Id.* An update will be sent to the RDEK program manager once 2023 provincial WNv surveillance data are received.

Since 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_6 October, three (3) in-state cases of WNv were reported in Washington State[11]. 33 mosquito pools tested positive for WNv. Two (2) horses/other mammals or birds tested positive in 2023. Of note, higher ambient temperatures from May–August contributed to a higher number of degree days during 2023, which likely contributed to human incidence of WNv activity.

The CDC identified 29 human WNv cases in Idaho[12]. Additionally, multiple mosquito pools and animals tested positive for WNv. All cases were identified within counties in the southwestern and southeastern portion of Idaho.

Zika Virus Summary

Information regarding Canadian Zika cases has been reported by the Public Health Agency of Canada since 2017 and Heath Canada will no longer be updating case counts[13]. HealthLinkBC, however, reports that zero Zika cases have originated in Canada due to presumed lack of vector mosquito species[14]. There have been human Zika cases reported in Canada prior to 2023, but 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 the east coast, but tested negative for Zika. There is currently a low risk for Zika virus to circulate within British Columbia.

[9] Seasonal update - Mosquito-borne disease surveillance - Vector-borne disease surveillance in Canada — Canada.ca
[10] https://www.canada.ca/en/public-health/services/publications/diseases-conditions/west-nile-virus-surveillance/2021/week-37-38-september-13-26.html
[11] http://www.doh.wa.gov/DataandStatisticalReports/DiseasesandChronicConditions/WestNileVirus
[12] https://www.cdc.gov/westnile/statsmaps/preliminarymapsdata2022/index.html
[13] https://www.canada.ca/en/public-health/services/diseases/zika-virus/health-professionals.html#_Surveillance_in_Canada
[14] https://www.healthlinkbc.ca/health-feature/zika-virus

2024 Program Recommendations

- Engage The Nature Trust in a discussion about options to reduce floodwater mosquito abundance within Bummers Flats

- Consider revision of RDEK Pest Management Plan to include the use of RPAS (Remotely Piloted Aircraft System – a.k.a "Drones") for larval treatments.

- Consider developing a project web page hosted by the RDEK that could include information about in-season treatments, up-coming aerial events, FAQs, reports, etc.

- Notify the Ministry of Environment of the RDEK intent to treat mosquitoes in 2024 under the RDEK Pest Management Plan. Notification should take place two 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).

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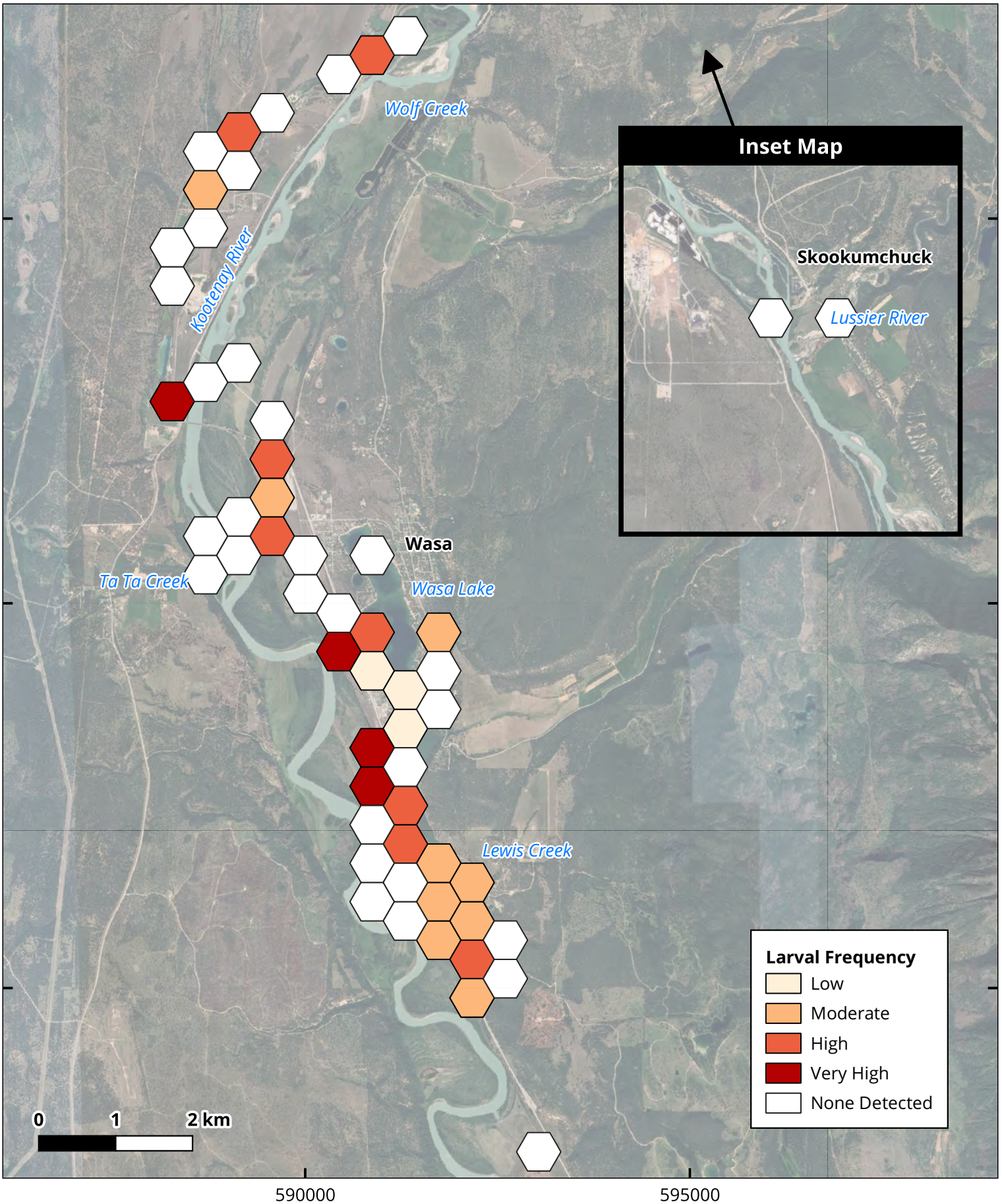
2023 Mosquito Larval Frequency at Sample Locations

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

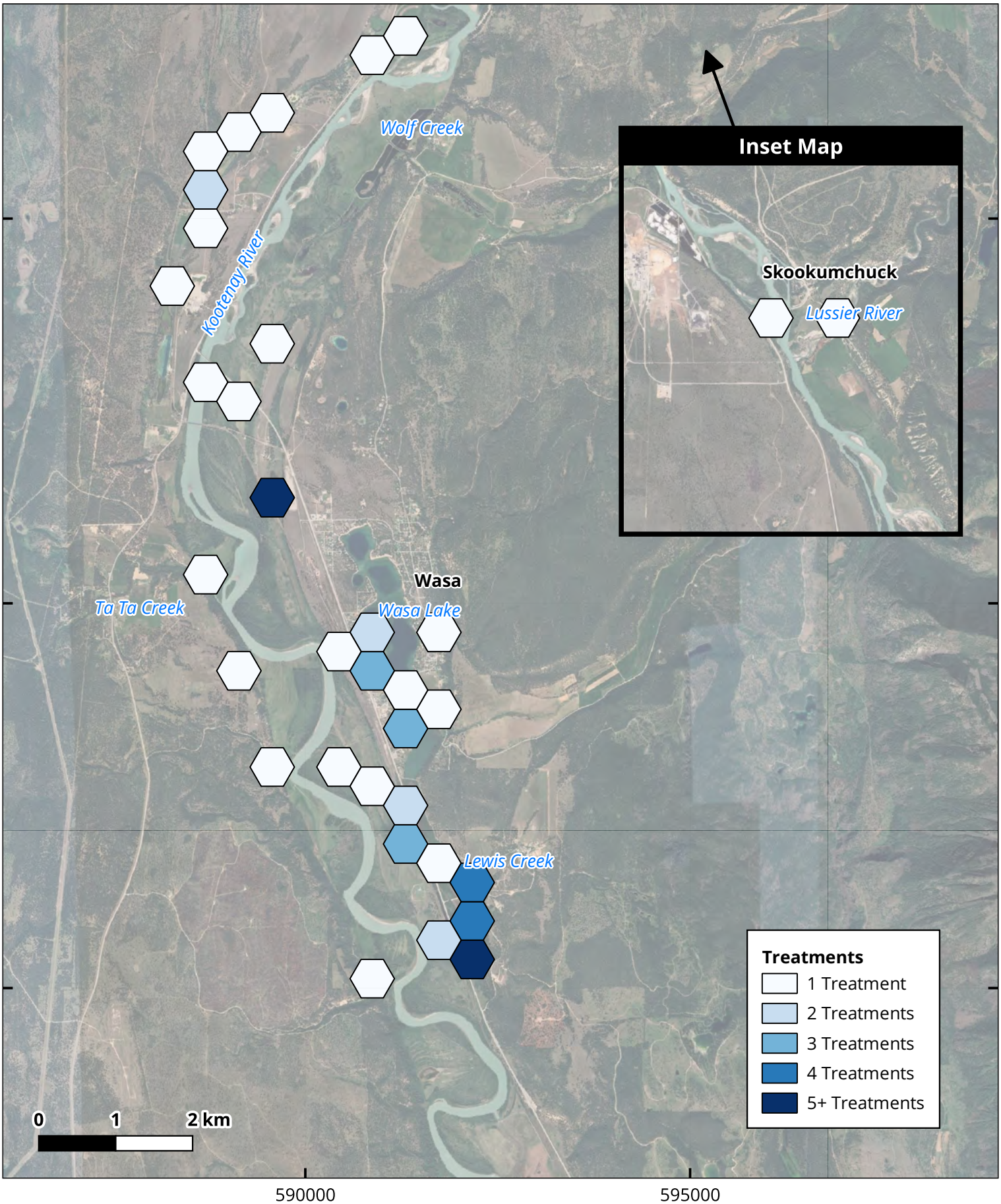


2023 Mosquito Larvicide Treatment Locations

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 – Treatment details (2023)

Date (Site)	Hectares Treated	Kg BTI applied
2023-05-13	**1**	**4**
Sawdust Pile	1	4
2023-05-29	**2.25**	**9**
Grassy Breakaway Areas	2.25	9
2023-05-30	**7.5**	**30**
Ashram Slough	1.75	7
Chanell 2	2	8
Ranch 2	2.5	10
Sawdust Pile	1.25	5
2023-06-01	**89.5**	**358**
Field off prairie road	2	8
Sweet Tooth #1	83.75	335
Sweet Tooth #2	3.75	15
2023-06-07	**4.4375**	**17.75**
Chanell 2	0.125	0.5
Grassy Breakaway Areas	1.3125	5.25
Sweet Tooth #1	3	12
2023-06-08	**8.375**	**33.5**
Ashram Slough	1.125	4.5
Rokosh	1.25	5
Sweet Tooth #2	1.25	5
Whites	4.75	19
2023-06-13	**2.25**	**9**
Muskrat Ranch	1	4
Ranch 2	1.25	5
2023-06-22	**15.5**	**62**
Lodgepole corner	0.25	1
Moans Road	1	4
Sweet Tooth #1	13	52
Whites	1.25	5
2023-06-23	**0.75**	**3**
Ashram Slough	0.25	1
Chanell 2	0.5	2
2023-06-26	**1**	**4**
Sweet Tooth #1	1	4
2023-06-28	**0.25**	**1**
Ashram Slough	0.25	1
2023-07-11	**1**	**4**
Sweet Tooth #1	1	4
Grand Total	**133.8125**	**535.25**