Driving Ecological Solutions for a Better Living

BIOLOGICAL CONTROL OF BITING INSECTS

Update on Bti and Practices Used

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1 G.D.G. Environment

The mission of G.D.G. Environnement is to improve the quality of life of citizens and ensure public health protection through ecological solutions in a context of sustainable development. Our team consists of professionals from the fields of biology, environment, forestry and entomology. Since 1984, the company has been involved in the biological control of biting insects (mosquitoes and black flies), offering services to over 45 municipalities in Québec. Our services have therefore touched the lives of some two million Quebecers. The company now offers an array of services to an increasing number of clients across Eastern Canada, with a labour force of more than 300 seasonal and 45 permanent employees.

We are proud of our achievements, reflected in the number of our major clients, including the Ministère des Transports du Québec, the Ministère de la Santé et des Services sociaux du Québec (for surveillance of the West Nile virus) and dozens of Public Health Units in Ontario. We are currently working in Northern Canada, with clients such as Serco Canada and the town of Fermont to ensure a better quality of life for workers, military personnel and residents.

Sustainable development is at the heart of G.D.G. Environnement's concerns. The team registered for and obtained Level 2 certification from RECYC-QUÉBEC, for its implementation of recycling. In addition, G. D. G. Environnement was awarded sustainable development certification from the city of Trois-Rivières in 2013, which was renewed in 2016 and 2018 for maintaining its environmental and social commitments. This type of recognition is earned by companies that fulfil concrete environmental requirements and undertake specific actions. Our achievements include protecting wetlands through donations to the Fondation Trois-Rivières durable (Trois-Rivières Sustainable Development Foundation) for the protection and enhancement of the Red Mill bog.

After more than 35 years of activity in the field of biological control of biting insects using Bti, we can say that the company's programs improve the quality of life of citizens and ensure public health protection in a context of sustainable development. The safety of Bti, the methods and technologies for applying it, its social acceptability and public health are four topics we would like to explain in more detail. We hope this document will contribute in improving the knowledge and understanding of the biting insect control programs the company provides.

2 Safety of *Bacillus thuringiensis israelensis (Bti)*

Authorized in Canada since 1982, Bti-based products are commonly used to control mosquito and black fly populations around the world. Larvicidal activity stems exclusively from the crystalline structure produced during the bacterium's life cycle. To be toxic, the crystal must be ingested by the target organism, which must have a highly alkaline pH digestive tract, enzymes capable of releasing the toxic molecules and, finally, toxin-compatible cellular receptors. The safety of Bti and the safety margins for the recommended operational doses indicate that Bti is harmless for micro and macro invertebrates, amphibians, fish, birds and mammals (Boisvert and Lacoursière, 2004).

2.1 Non-Target Wildlife

Since the beginning of Bti's use (40 years ago), there has been a scientific consensus on the safety of Bti, as evidenced by the document prepared for the Ministère de l'Environnement du Québec in 2004 (Boisvert and Lacoursière, 2004). It can be said, however, that counter arguments have also been put forward, including research by Poulin et al., 2010, which raised uncertainties about the indirect impact of Bti treatments on non-target wildlife. Nevertheless, long-term studies in Minnesota (Niemi et al., 1999), Sweden (Persson, Vinnersten et al., 2010), France (Caquet et al., 2011; Lagadic et al., 2014, Duchet et al., 2015, Lagadic et al., 2016) and Germany (Timmermann and Becker, 2017) did not show any direct or indirect impact of Bti on secondary consumers. The study by Poulin et al., 2010, is now contested by several researchers who refute, among other things, the initial ecological heterogeneity between the treated and untreated areas chosen for the study (Lagadic et al., 2014) and the lack of research on the availability of prey, the conclusion of which is based on an hypothesis (Timmermann and Becker, 2017). Timmermann and Becker, 2017 published a study on the impacts of routine Bti treatments on the availability of flying insects as prey for aerial predators. Their conclusion is as follows:

> "Our results are not in line with those of Poulin et al., 2010, who reported that direct and indirect impacts of Bti treatment on the abundance of Nematocera were responsible for lower breeding performance of *D. urbicum* in France. However, prey availability was not investigated by Poulin et al., 2010. Rather, the authors assumed that the number of Nematocera and their arthropod predators was lower in treated areas because their number was lower in the birds' diet. According to our observation, these conclusions are questionable; especially as Lagadic et al., 2014 pointed out that there were considerable environmental discrepancies between treated and untreated areas in Poulin et al., 2010. […] Secondly, the manner in which mosquito control was conducted in the Upper Rhine Valley showed no direct or indirect effects on aerial insect abundance, which would indicate a negative impact on food resources for aerial feeding predators." (Timmermann and Becker, 2017)

It is noteworthy that scientific literature shows that mosquito remains do not appear in the stomach contents or faeces of birds, who prefer to consume more abundant prey, which are easier to catch because of their size. Moreover, a judgment in France in 2014 rejected the viewpoint of groups that wanted to ban the use of Bti based on the work of Poulin et al., 2010[1]. The judgment specifies that after consulting "the scientific work available in France and abroad, it seems difficult to conclude that these mosquito control activities have a significant impact on the state of conservation of the sites".

Another publication released in 2015 attempted to demonstrate a possible impact, under overdose conditions, on amphibians (Lajmanovich et al., 2015). Since then, two other articles were published in 2018 and 2019 in Germany, refuting the results of that study, reporting no mortality and no impact on development (Allgeier et al., 2018, Schweizer et al., 2019). Previously, no direct or indirect effects of Bti on amphibians had been reported following several studies (identified in the article by Boisvert and Boisvert, 2000).

A study conducted in Minnesota on leopard frogs in the laboratory and in the field for two consecutive years (Johnson and Johnson, 2001) and another in India in 2011 (Tiwari et al., 2011) reached the same conclusions. Finally, a study conducted in Trois-Rivières (Leclair et al., 1988) on native frogs showed no

[1] http://www.eid-med.org/actualites/des-associations-retoquees-en-justice

effect on the development of tadpoles feeding on mosquito larvae killed by Bti. G.D.G. Environnement has been working for 35 years in the field of biting insect control and the company has never observed any mortality or decline in the population (eggs, tadpoles or adults), despite treatments carried out year after year.

2.2 Canadian Studies

Two studies were conducted in recent years in Canada. The University of Ottawa, sponsored by the city of Ottawa, studied the effect of Bti on chironomidae insects in the field. This study was conducted over three years and the findings are expected to be published shortly. Initial communications from a person involved in the study revealed that there was no population decline or biodiversity loss among chironomidae and that the use of Bti had no impact on trap contents (Liam Epp, personal communication). A second study, commissioned by Québec's Ministère des Forêts, de la Faune et des Parcs (MFFP), was conducted this year on the impact of Bti on the American toad (*Anaxyrus americanus*) and on the wood frog (*Lithobates sylvaticus*). The results of this study carried out by Québec's Institut national de la recherche scientifique should be available in 2020.

2.3 Food Web

In wetlands, a balanced ecosystem will include a food web, where black fly and mosquito larvae are not the only source of food for aquatic predators. The greater the food web's diversity, the less likely it is that the complete or partial elimination of a single species will have significant consequences.

In the case of the biological control of biting insects, biomass reduction is only partial and temporary since treatments are carried out only when the larvae have reached a certain stage of development, meaning they remain available to predators for a good period of time. In addition, during treatment, larvae are always available in the environment for some time for plecoptera, other aquatic insects and fish (Wipfli and Merritt, 1994). Finally, the interval between treatments also gives the biting insects time to recolonize the environment and become available again a few days after treatment. Biological control of biting insects has a low impact on the food web as it affects a highly diversified biocenosis with a high biomass (Figure 1).

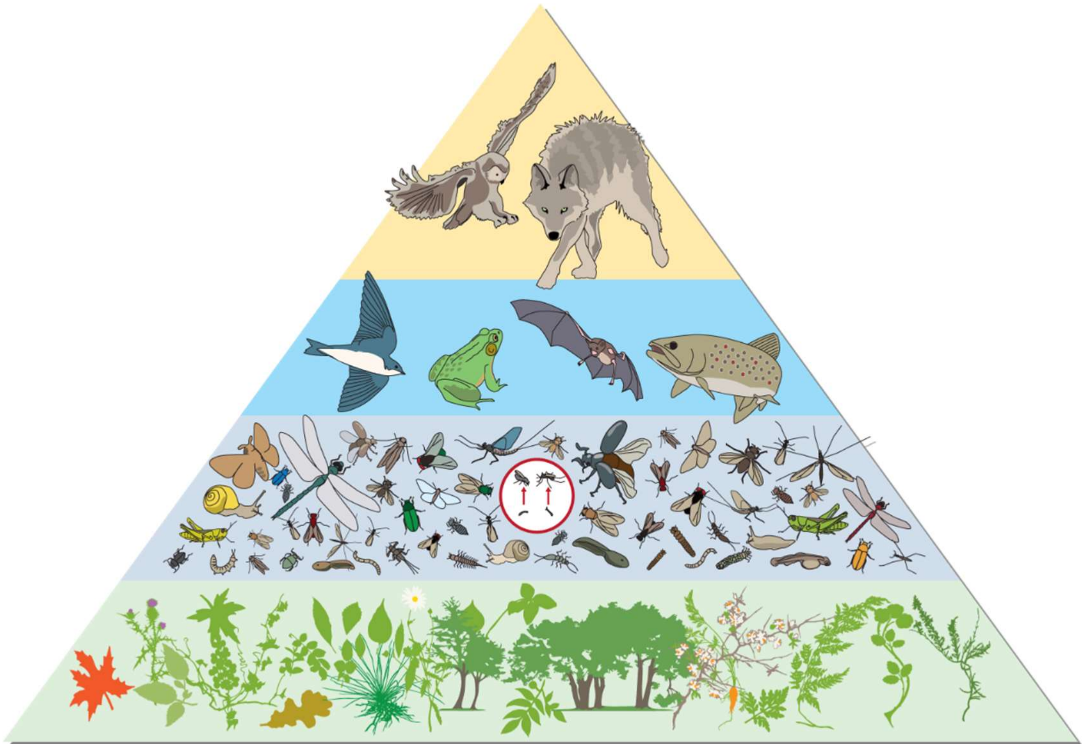


Figure 1: Example of a food web with mosquitoes and black flies (highlighted in the red circle)

2.4 Resistance

There is no resistance to Bti detected in nature. The complexity of the mode of action between the pathogen and the target insect means that the possibility of an insect developing resistance is low. Indeed, this complexity results from the combined and synergistic action of the four proteins associated with the toxic process of the crystals. Although it is theoretically possible to develop resistance to Bti crystals in the field, the probability of such an event occurring is very low. In addition, in Québec, only a few Bti treatments are carried out during the summer and individuals from untreated areas mix with exposed populations, hindering the development of resistance.

In Germany, a mosquito control program using Bti has been in place since 1981. Over the years, it is estimated that 189 generations of *Aedes vexans* have been subject to selection pressure due to Bti. A recent study showed that no resistance has developed at treated sites for 36 years (Becker et al., 2018). These results are in agreement with those of da Silva Carvalho et al., 2018, which showed no resistance to Bti following exposure of 30 generations of *Aedes aegypti*.

3 Public Health

3.1 Effect of Bti on Humans

Mammals do not have an apparatus that can activate the toxin contained in Bti and therefore it is safe for humans. In its 2006 re-evaluation of the registration of *Bacillus thuringiensis, the* Pest Management Regulatory Agency (PMRA) states that:

> "Consumption of treated products cannot be expected to pose a risk to the public, children and infants. The risk of exposure through drinking water is negligible. The low toxicity of *Bacillus thuringiensis* and the demonstration of its safety suggest that human exposure through drinking water does not pose a significant risk."[1]

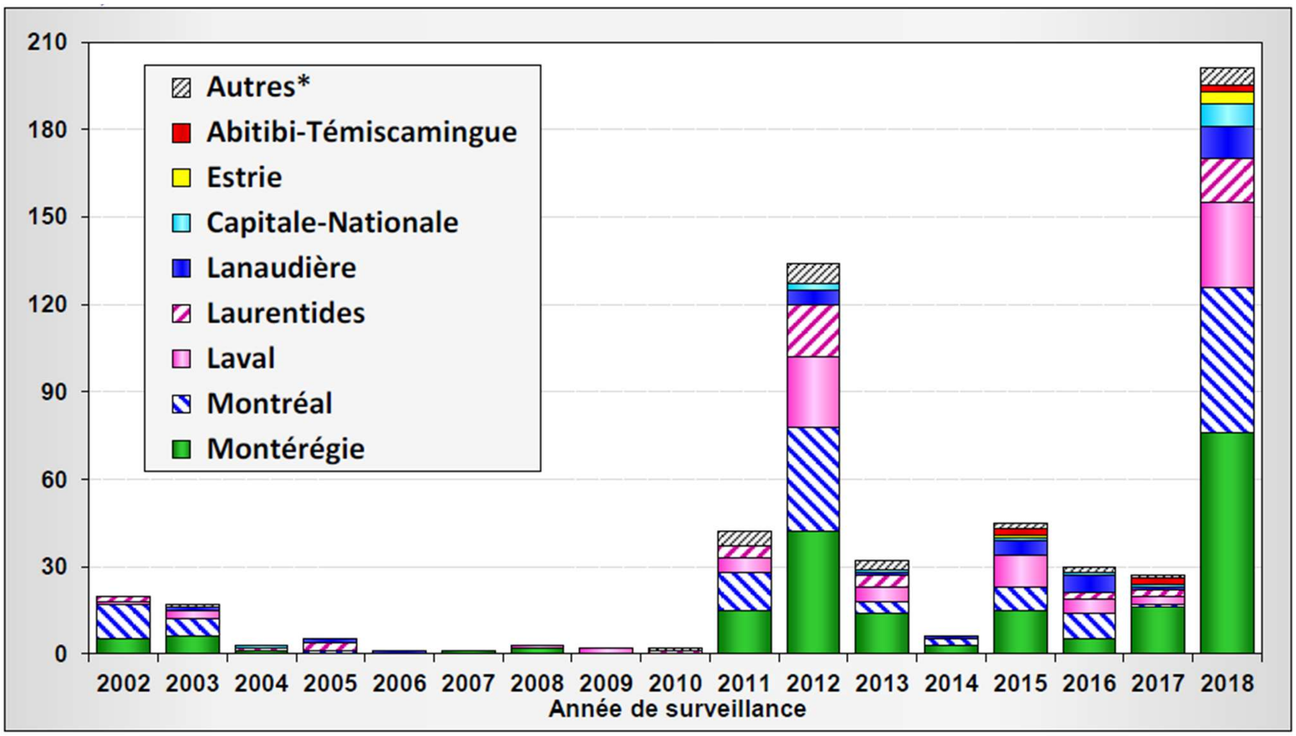
In addition, no harmful toxic effects, infectivity or pathogenicity by the oral, inhalation, intraperitoneal or dermal routes were observed. It appears that no known toxin or metabolite of *B. thuringiensis* is an endocrine disruptor or has a toxic effect on the immune system. It is important to note here that the PMRA has access to the complete list of ingredients (even those kept confidential) for each of the registered formulations. Human health and ecotoxicity studies are conducted on formulations and therefore include the effects of additives or adjuvants in their results. The U.S. Environmental Protection Agency (EPA) also concluded that it was reasonable to believe that dietary exposure to residues of *B. thuringiensis* would be safe for infants and children. The World Health Organization Pesticide Evaluation Scheme (WHOPES) published a report in 2009 authorizing direct application in drinking water to control certain mosquitoes in countries with diseases such as malaria or yellow fever. This clearly shows that the product is completely safe for humans.

3.2 Mosquito-Borne Diseases

In addition to being harmless to humans, Bti reduces the risk of the spread of certain diseases by eliminating their vectors. Indeed, the mosquito is the most deadly animal in the world because of the diseases it can transmit following its bite. A book that was recently published states that "some extrapolated statistics indicate that nearly half of all human beings who have lived to date, or about 108 billion people, have died from mosquito-borne diseases". (Winegard, 2019).

Fortunately, Québec's climate, with its cold winters, helps to regulate mosquito populations and prevents some particularly dangerous species from establishing themselves here. However, climate change is currently expanding mosquito territory. Researchers have found *Aedes albopictus*, nicknamed the tiger mosquito, in southern Ontario. This mosquito is known to transmit diseases such as the Zika virus, Chikungunya and Dengue fever. In addition, West Nile virus is endemic in Québec, and the number of cases of this reportable disease varies according to weather conditions, mainly as a result of heat episodes that are becoming more frequent in our latitudes. In the 2018 season in Québec, there were reports of 201 human cases, 15 deaths and 15,000 infected people, using the 1% ratio of neurological disorders (Figure 2).

[1] https://www.inspq.qc.ca/es/node/1127



* La catégorie « Autres » comprend les régions qui ont rapporté entre 1 et 3 cas depuis 2015 (période 2015-2018), soit celles de Bas-Saint-Laurent, Saguenay–Lac-Saint-Jean, Mauricie et Centre-du-Québec, Outaouais, Gaspésie–Îles-de-la-Madeleine et Chaudière-Appalaches. Par ailleurs, depuis le début de la surveillance, en 2002, aucun cas n'a été rapporté par les régions Côte-Nord, Nord-du-Québec, Nunavik et Terres-Cries-de-la-Baie-James.

Source : INSPQ, données extraites de l'Infocentre le 1[er] mai 2019.

Figure 2: Number of West Nile Virus cases by reporting year and region of residence, Québec, 2002 to 2018.

PHOTO: Others, Year of surveillance, The category "Others" includes regions that reported between 1-3 cases since 2015 (2015-2018 period), including the Bas-Saint-Laurent, Saguenay-Lac-Saint-Jean, Mauricie and Centre-du-Québec, Outaouais, Gaspésie-Îles-de-la-Madeleine and Chaudière-Appalaches regions. It is noteworthy that since the time surveillance began, in 2002, no case has been reported in the Côte-Nord, Nord-du-Québec, Nunavik and Terres-Cries-de-la-Baie-James regions.
Source: INSPQ, data taken from the Public Health Expertise and Reference Centre on May 1, 2019.

In 2016, leading world organizations such as the World Health Organization (WHO) recommended a return to larvicide application for healthy vector control. According to WHO, the resurgence of Dengue fever and the spread of emerging diseases such as Zika and Chikungunya are due to reduced funding and vector control efforts. With climate change and global warming in particular, the mosquitoes that carry these diseases are at the gates of Québec and are gradually moving northward. West Nile virus is already present on our territory and aerial spraying was required in 2003 due to an outbreak.

3.3 Benefits of Mosquito Population Control

Recent studies have quantified the impact of mosquitoes on people's physical health. They conclude that, even in the absence of disease transmission, mosquito infestation has a negative impact on health and that, when a control program is in place, children's physical activity is higher (Halasa et al., 2014; Worobey at al., 2013; Hirsch and Becker, 2009). A study in two counties in New Jersey indicates that about 60% of residents did not benefit from outdoor activities, at least to some extent, due to mosquitoes (Halasa et al., 2014). In addition, residents surveyed rated the enjoyment of outdoor activities as being as important as living in a safe neighbourhood, even higher than living in a clean neighbourhood. More and more people are also developing allergic reactions to mosquito bites. In some cases, these hypersensitive reactions can lead to hives, bronchospasms and even anaphylactic shock (Feuillet-Dassonval et al., 2006).

4 Legal Framework

Although Bti is a biopesticide and its safety has been demonstrated for many years, biting insect control programs are nevertheless governed by the Environment Quality Act (EQA) and its regulations. A company seeking to treat with Bti must first obtain a permit from Québec's Ministère de l'Environnement et la Lutte contre les changements climatiques (MELCC). In addition, company employees carrying out treatments must obtain a certificate for users of pesticides, specific to operations involving the control of biting insects. Finally, all control programs must first go through the MELCC environmental authorization application process. During that process, a wildlife advisory is requested from the MFFP, and certain areas may be restricted depending on the species present on the territory. With the modernization of the Environmental Quality Act, the MELCC is currently studying the possibility of classifying Bti as low risk.

On federal lands, Bti users must also verify for the presence of species at risk and apply for a permit under the Species at Risk Act (SARA) from Environment and Climate Change Canada (ECCC). In point of fact, G.D.G. Environnement contacted the ECCC last spring about an area that included the Chimney Swift, Eastern Whip-poor-will, Common Nighthawk, Canada Warbler, Barn Swallow, Bank Swallow, Little Brown Bat, Northern Bat and Eastern Pipistrelle. ECCC's response was that, in this particular case, G.D.G. Environnement was not required to obtain a permit because the use of Bti is not likely to contravene SARA for the species present at this location (see ECCC's letter in the Appendix).

Where aerial spraying is required, in addition to complying with the EQA, operators must comply with Transport Canada requirements. All aircraft are certified by Transport Canada for this specific type of application. All pilots are also certified to provincial and Canadian standards. Flight operation policies and procedures are written in accordance with the standards governing the use of aircraft for aerial work, in accordance with the Canadian Aviation Regulations (CARs). Pilots avoid flying over inhabited and sensitive areas and comply with Transport Canada directives (altitude, wind speed, manoeuvring, visual flight rules, etc.).

5 Methods Used

The control of biting insects with Bti is already an innovative practice since it uses a biopesticide. Companies and/or organizations follow an integrated pest management plan as part of their control program. To better understand the context in which operations take place, the following is a summary of the methods most commonly used.

First, there are two types of control programs depending on the nuisance observed in the municipality: the treatment of mosquito populations and the treatment of black fly populations. Mosquito larvae develop in standing water while black fly larvae develop in water that flows. It is very rare that aerial applications are carried out to control black flies.

5.1 Mosquito Treatment Sequence

For mosquito populations, the ideal time of treatment, taking into account efficacy and label recommendations, is when the majority of mosquito larvae have reached development stages 3 and 4, just before pupation. The first treatment of mosquitoes in the spring is predictable and synchronized with snowmelt and spring flooding. Subsequent treatments are carried out depending on when the larvae hatch. The outbreak of summer biting species is highly dependent on rainfall. As early as mid-May, heavy rainfall can allow so-called summer species to hatch. *Aedes vexans* is the most abundant species. Certain habitats can be treated several times. Field teams are trained in mosquito species recognition and are supported by entomologists. The main species targeted by control programs are those of the *Aedes-Ochlerotatus* group, which includes the majority of biting species. The following chart shows the evolution of spring and summer mosquito populations, without treatment (Figure 3), and with Bti treatment (Figure 4).

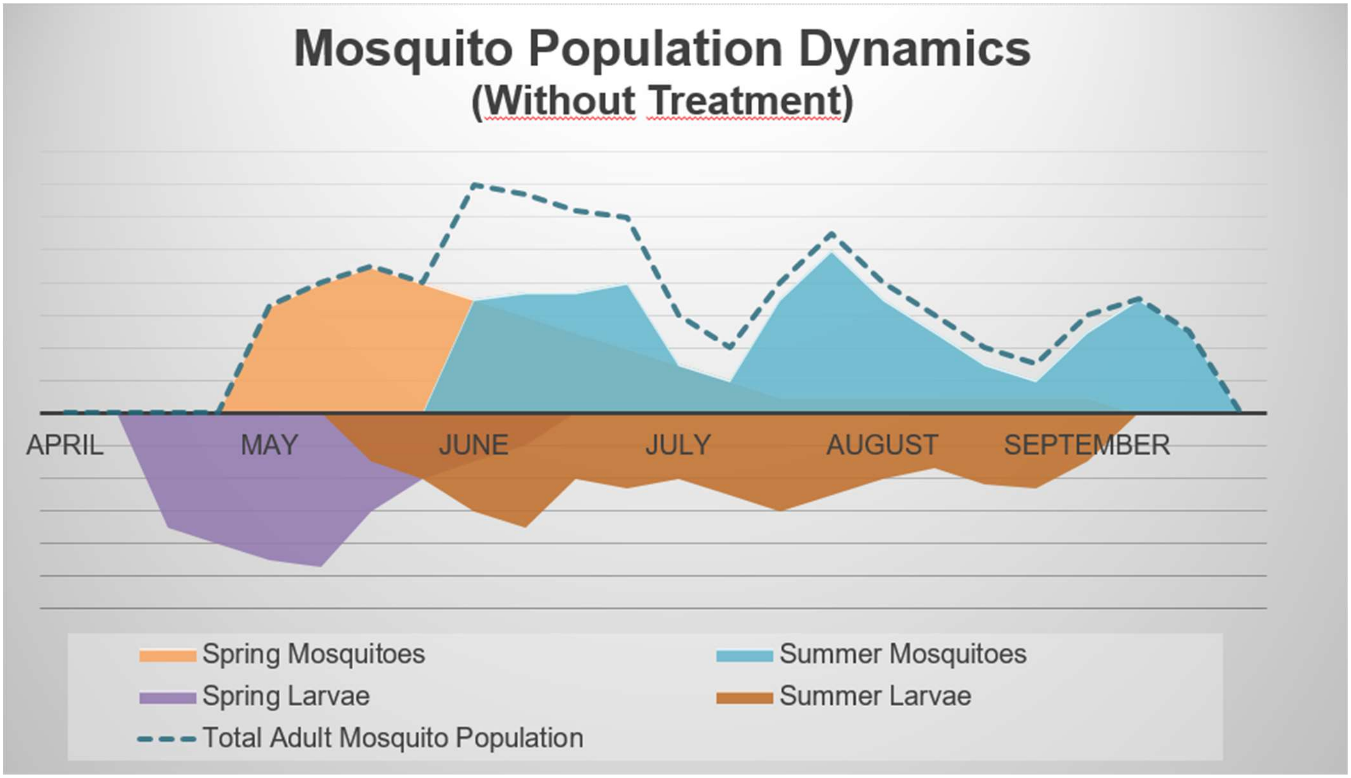


Figure 3: General cycle of larval and adult mosquito populations in Québec without any treatment.

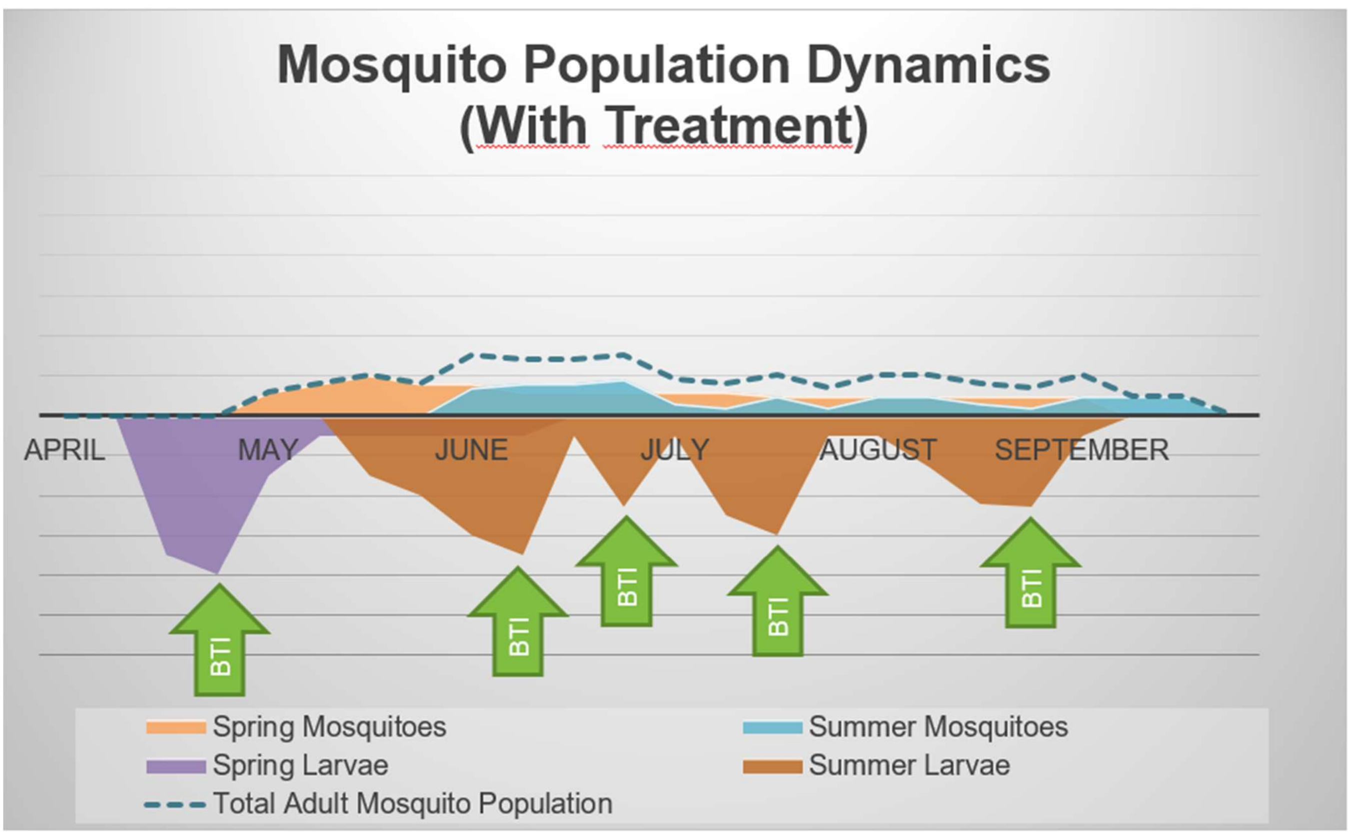


Figure 4: General cycle of larval and adult mosquito populations in Québec with Bti treatment.

It should be noted that mosquito populations are never exterminated entirely and there is always a residual nuisance. The purpose of biological control of biting insects is to reduce mosquito populations to a level that is acceptable to surrounding populations. Sometimes, the residual nuisance can even be quite significant.

5.2 Black Fly Treatment Sequence

For black fly populations, the position and number of treatment points may change depending on the location of the larvae. The effective range of the product varies greatly depending on the hydrology and physico-chemical conditions of the watercourse. The flow of small rivers is highly variable throughout the season (snowmelt, rainfall or drought, beaver dams) and this modifies the number and distribution of treatment points. Some warmer watercourses may be treated up to ten times during the season.

5.3 Before and After Treatment

Regardless of the type of treatment considered, a sampling of the habitats always precedes spraying operations. Treatments are only carried out if there are larvae of species that bite humans. Prospecting of various habitats allows controls to be carried out at the appropriate time. There is no blanket treatment carried out as a preventive measure. Quality control of treatments is ensured in several ways. The effectiveness of applications is assessed by larval mortality 24 to 48 hours after larvicide applications. Then, the resulting nuisance is assessed using standard entomological net testing and Centre for Disease Control (CDC) light traps.

5.4 Aerial Application

Products used for the treatment of mosquito and black fly larvae are all biological products and available in liquid form (VectoBac 1200L) or in granular form (VectoBac 200G). Granules mixed with crushed corn are used in aerial applications. This granular formulation does not contain any residues that could drift or solvents that could evaporate into the atmosphere. A wind of below 10 knots has virtually no impact on the granular formulation, which falls to the ground and penetrates vegetation to reach aquatic environments. The risk of drift is therefore practically nonexistent.

Biological control operations use aerial applications for large surface habitats, habitats that are difficult for ground technicians to access or sites requiring little physical disturbance. Aerial applications are essential in spring and during major impoundments (heavy rainfall not absorbed by the ground). Recently, it has also become possible to use drones for spraying. Spring aerial applications are carried out over a period of about two weeks.

Aerial applications are highly accurate due to the use of a GPS guidance system. Using a granular formulation prevents drift and evaporation. In addition, this work is supervised by Transport Canada as mentioned in the section Legal Framework.

5.5 Treatment Area

On the maps provided with environmental permit applications, the treatment area indicated corresponds to the potential treatment area. It should be noted that the entire area is never treated, but only the habitats where water is found (following snowmelt or rainfall), and in which larvae of human biting insects are found. Since it is impossible to predict flooded areas, treatment maps cover a larger area than what is actually treated. Often, the first treatment, which follows snowmelt, will cover a larger area than the second, whose area could be reduced by half. Requesting permission to treat a larger area allows for the unexpected occurrence of seasonal weather conditions.

In addition, it is surprising to see the total treatment area required to protect an entire municipality. The intervention areas represent a very small fraction (under 1%) of the total territory. To explain how the surface area for treatments is determined, it is good to have a clear understanding of the biology of biting insects. Females of most mosquito and black fly species require a blood meal in order for their eggs to develop. To find this blood meal, they can travel varying distances depending on the species, the environment in which they are located, the presence of migration corridors, the weather, etc.

According to scientific literature, mosquitoes can easily fly up to several kilometres from their emergence site, but 2 km is the average for several species. Black flies have an even greater range of action, the average being between 4 and 6 km. Determining the limits for intervention is a complex process and unique for each project. For mosquitoes, an intervention limit of 2 km around the target area is usually sufficient to maintain a decrease of at least 80% of the nuisance. There are also migration corridors that favour the movement of biting insects, such as lakes enclosed between two mountain ranges or hydroelectric power lines. These corridors lead to a reinvasion that leads to new spawnings in treated water bodies and streams, from which mosquitoes and black flies will emerge again if they are not treated regularly throughout the summer.

Bti is applied directly to wetlands and streams where it selectively attacks mosquito and black fly larvae. This method considerably reduces the impact on the territory, since the larvae are concentrated in specific areas. The control of adult biting insect populations would require action throughout the territory.

6 Social Acceptability

All municipal biting insect control programs are carried out at the request of the residents of a municipality with a nuisance problem. Biological control programs for biting insects are implemented at the request of groups of citizens and are subject to several public consultations. Projects can develop over many years, and go through several stages, before being implemented. Here is an example of the consultation process for implementing the programs:

1. Public presentations on several occasions at various municipal council meetings;
2. Public presentations at information sessions created specifically for this topic and advertised in the media for several weeks;
3. Official survey conducted by the city*;
4. Public tender process;
5. Adoption of resolutions by unanimous vote of the elected representatives;
6. Display on each citizen's tax bill;
7. Implementation of a communication plan, including, among other things, a mosquito info-line, distributed and advertised by both the municipality and G. D. G. Environnement.

*Examples: the city of Nicolet in 2018: 95% in favour; the city of Trois-Rivières in 2005 and 2019: more than 80% in favour

The public nature of municipal biological control (Bti) programs requires several stages of consultation, clear communication of all aspects of the program and adoption by a majority of stakeholders. Municipal environmental committees also have competent and involved local resources that reflect social acceptability. In such a context, the use of impact assessment becomes much less relevant.

The control of biting insects does not increase pressure on wetlands. On the contrary, biological control allows for better cohabitation and increases the civic acceptability of wetlands in urban and peri-urban areas, thereby protecting sensitive areas. The loss of such habitats is one of the causes of the decline of insectivorous birds and aquatic biodiversity.

It should be noted that biting insect control programs using Bti actually ensure control in a more environmentally friendly way for citizens and the environment. Indeed, some of the population, without this alternative, would turn to other solutions such as individual chemical pesticides (coil, spray can, fumigation, etc.) or non-selective traps. In addition, the justification for the biting insect control program is included in the application process for a ministerial authorization for the use of pesticides (Directive 017) and is therefore included in the environmental authorization application.

All these processes are also intended to take into account the precautionary principle. Despite the scientific consensus on the low impact of biological control of biting insects, there are several laws, regulations and standards that strictly regulate the use of Bti. All the guidelines in place reduce the risks to almost zero and make it possible to establish, as in the French judgment of 2014, that there is an absence of any significant impact on the environment. According to the very definition of the precautionary principle, stated in Principle 15 of the Rio Declaration, 1992: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation", biological control of biting insects poses no serious or irreversible risk.

7 Alternatives

There is an increasing number of alternative methods for the control of biting insects on the market. However, alternative methods proposed have not proven their effectiveness. Proposed non-invasive methods include biological control using predators (e. g. bats, birds, fish), the use of plant extracts, the use of genetically modified mosquitoes or the use of traps. Recently, carbon dioxide baited traps (Qista brand) have become popular. However, such alternative methods are not viable for an entire municipality. It should be noted that mosquito traps have a very limited radius of attraction. The number of traps needed to protect a large city would be in the order of several thousand. The acquisition and operating costs would therefore amount to tens of millions of dollars. It is naive to think that a municipality in Québec could set a sufficient number of traps to reduce mosquito populations below an acceptable threshold, which would allow people to benefit from outdoor activities. At the municipal level, it would be financially and physically unrealistic. In addition, traps capture many other insects (over 40%) that are a component of the diet of some predators. Conversely, programs using Bti are selective against biting insects.

When the different methods of controlling biting insect populations are presented in a decision matrix, it becomes quite clear that the use of Bti is the best method considered (Table 1).

Table 1. Decision matrix with different methods of controlling biting insects

	Nothing	Chemical Control	Drainage	Predators	Traps	Personnal Protection	Bti
Efficacy		+ + +	+		+	+	+ + +
Impact on surroundings		− − −	− −	+	− / +	−	−
Impact on health	− −	−	+			+	+
Total	-2	-1	0	1	1	1	3

8 Conclusion

As mentioned above, the industry involved in the biological control of biting insects has touched the lives of some two million Quebecers. Biological control is the most logical and ecological solution. Larvicides target larvae while they are confined to their developmental habitats. Conversely, all other solutions target adult mosquitoes that are dispersed and less vulnerable. The significant benefits, in terms of reduced insect concentrations and the non-use of insecticides and chemical repellents, make this method a commonly used control method.

9 Further Information

https://www.infobti.com/

http://www.environnement.gouv.qc.ca/pesticides/virus-nil/bti/index.htm

https://www.inspq.qc.ca/es/node/1127

https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/fact-sheets-other-resources/bacillus-thuringiensis-subspecies-israelensis.html

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Appendix