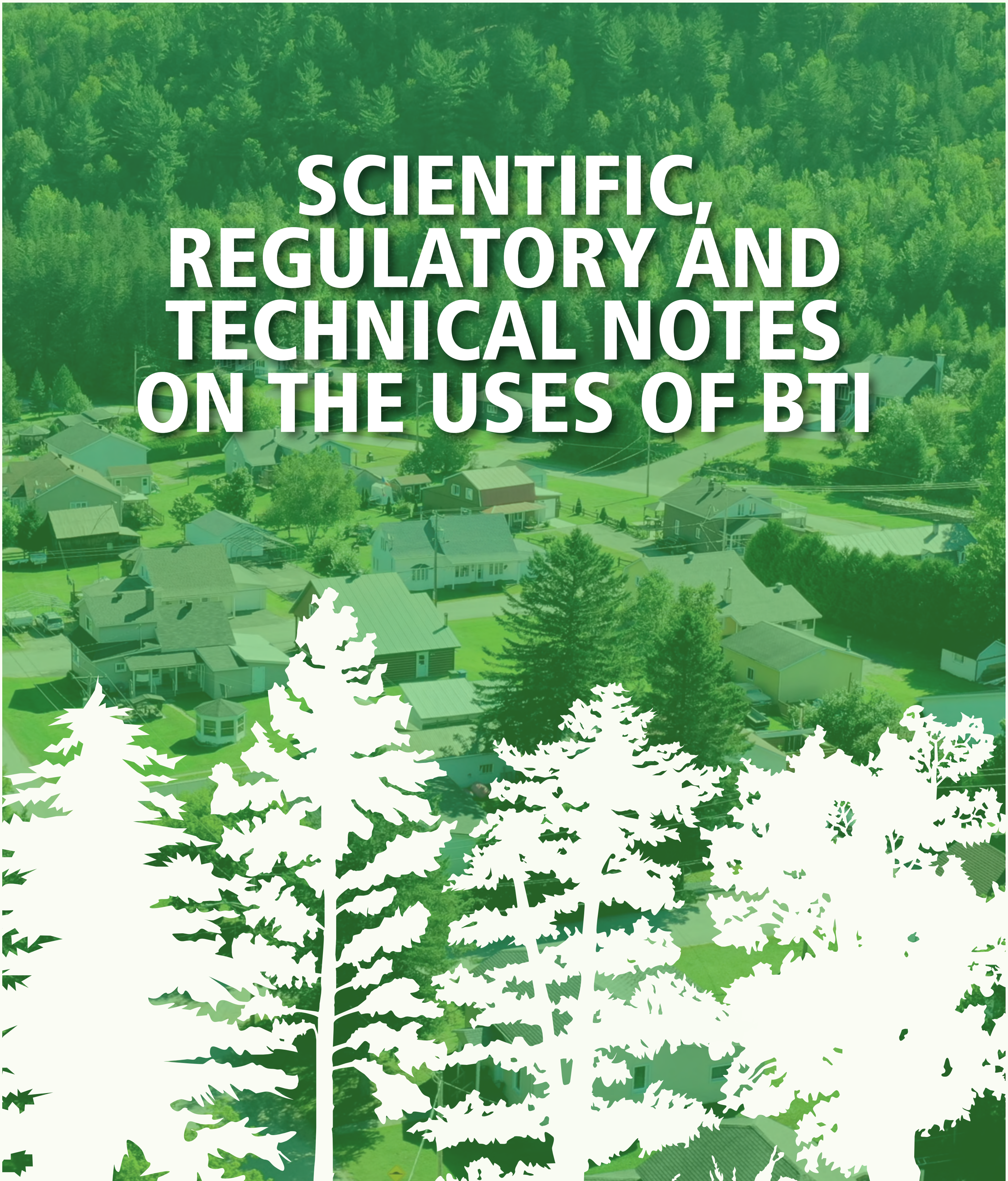
SCIENTIFIC, REGULATORY AND TECHNICAL NOTES ON THE USES OF BTI



UPDATE 2025

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SUMMARY

***Bacillus thuringiensis* var. *israelensis* (Bti)** is a bacterium used as a biological insecticide to control mosquito and black fly populations, specifically targeting their larvae. Its use is widespread worldwide to reduce nuisance and the risk of disease transmission by these insects. Bti produces toxins in the form of protein crystals, which dissolve in the digestive system of larvae when they ingest them while feeding, destroying the stomach walls and causing death. Unlike chemical insecticides, which can pose significant risks to human and animal health, Bti is safe for humans and other vertebrates, according to all public health advisories. Prior to registration in Canada, the Pest Management Regulatory Agency (PMRA) rigorously assesses the safety of Bti products. Manufacturers must provide complete data regarding the product's formulation and its potential effects on health and the environment. Although Bti has been shown to primarily target mosquito and black fly larvae, the safety of Bti and the safety margins for recommended operational doses indicate that Bti is safe for use in micro- and macro-invertebrates, amphibians, fish, birds and mammals. According to a re-evaluation published by the Canadian and Quebec authorities, it states that B. thuringiensis is not entering the environment in a quantity or concentration that has an immediate or long-term harmful effect on the environment or its biological diversity. By reducing mosquito populations, Bti helps reduce the risk of vector-borne diseases such as West Nile virus and eastern equine encephalitis. In Canada and Quebec, the use of Bti is strictly regulated. Bti products are classified as 'restricted,' meaning they may only be applied to specific areas where the target larvae are found. Applicators must be certified, and in Quebec, additional authorization is required. Bti is applied directly to aquatic environments where mosquito and black fly larvae develop, such as marshes, ponds and rivers. The application can be by ground or air and requires the necessary permissions. The public nature of biological larvicide control programs in municipal settings requires several stages of consultation, clear communication of all aspects of the program, and majority approval. All municipal biting insect control programs are carried out at the request of the citizens of a municipality facing a nuisance problem and are the subject of several public consultations. The results of these surveys, conducted by recognized firms or during consultations, confirm the support of citizens for the control of biting insects using biological larvicides.

In Canada, the use of Bti remains marginal compared to synthetic pesticides, which are much more toxic. Bti is an effective tool for the control of biting insects and the reduction of vector-borne diseases. Its use requires the pursuit of transparent risk-benefit assessments, as well as continuous monitoring to document its impacts on biodiversity and the food web.

BACKGROUND

More than ever, Canadians are concerned about maintaining biodiversity and preserving our natural ecosystems. Fortunately, there are biological control tools for the control of insect pests and biting insects, such as *Bacillus thuringiensis var israelensis (Bti)*, which are environmentally friendly due to their short half-life, biodegradability and very limited impact on non-target insects (Bordalo et al., 2020). Bti is a microbial-based formulation and is used in bloodsucking insect control operations. Unfortunately, despite the increasing use of biological control tools in Canada and around the world, several factors have contributed to a substantial loss of biodiversity, mainly due to human activity (Amendt, 2021, Theodorou, 2022, Quandahor et al., 2024, Wan et al., 2025):

1. **Urbanization: The expansion of cities fragments ecosystems, isolating animal and plant populations**
2. **Deforestation: The conversion of forests into agricultural land, urban areas or infrastructure reduces the habitats available to many species.**
3. **Human infrastructure: Roads, dams and other structures fragment habitats and disrupt migration.**
4. **Intensive agriculture: The use of monocultures, pesticides and fertilizers impoverishes soils and destroys habitats.**

Despite the increasing use of biological control tools in Quebec and around the world, several factors—mainly related to human activity—have led to a significant loss of biodiversity.

First, **urbanization** is currently considered to be one of the main factors in biodiversity loss. This loss is reflected in the fact that most organisms have difficulty tolerating the environmental alterations associated with urbanization (Braby et al. 2023). By analyzing the differences in abundance between urbanized and non-urbanized environments of more than 800 species of birds around the world, it has been possible to observe that a large part of this loss is associated with the lack of adaptation of these species to this disturbance (Sol et al., 2014).

Deforestation, on the other hand, is the result of human population growth and the abusive exploitation of natural resources (Verma et al., 2020). Of all the species of plants, amphibians, reptiles, birds, and mammals that have disappeared since 1500 (AD), 75% have been affected by overexploitation of forests and agricultural activity, or their synergistic effect (Maxwell et al. 2016). It is considered one of the main threats to biodiversity since forests are home to a large part of the entomological and avian fauna. (Dar et al., 2021, Braby et al., 2023).

Deforestation has a well-documented direct negative impact on biodiversity.

Environmental changes, **through the addition of human infrastructure** directly alters the habitats of plant and animal populations by causing their fragmentation, modification and loss of local habitats (Simkins et al., 2023), which has a direct impact on the widespread decline in biodiversity (Tian et al., 2020). A particular example of this phenomenon has been studied in the Columbia spotted frog, *Rana pretiosa*, in Yellowstone National Park, where no sanitary measures (pesticides, herbicides, fungicides) are put in place to control any undesirable species. Between the mid-1950s and the mid-1990s, the population of *R. pretiosa* declined by nearly 80%. The number of active breeding sites has decreased from 3 sites in the 1950s, to 2 and then 1 in the 1990s, and none after 2007 (Patla & Peterson 2022). The causes of the Columbia Spotted Frog population decline include:

1. **Construction of a road in the 1970s that crossed the study area**
2. **Development of water sources upstream of the study area**
3. **Construction of facilities around the study area to support the expansion of human activities.**

This long-term study provides unique insights into how land use can affect amphibian populations, even in protected areas (Patla & Peterson, 2022).

Another significant element in the list of factors contributing to a substantial loss of biodiversity is **intensive agriculture** (Wan et al., 2025). Unfortunately, the increase in agricultural production is inevitably accompanied by an increase in the use of chemical fertilizers, herbicides and other synthetic pesticides such as glyphosates, the use of which has grown rapidly in recent years (MELCCFP pesticide sales report, 2022).

Even at low doses, synthetic pesticides can have significant impacts on non-target species.

The use of synthetic pesticides, such as organophosphates and pyrethroids, can have significant toxic effects on wildlife, disrupting ecological communities. These substances, often non-specific, affect non-target species, including pollinators such as bees, aquatic insects, birds and mammals. Exposure to these chemicals can impair critical physiological functions, such as reproduction, growth, and feeding behavior, and cause sublethal effects, such as sensory or cognitive deficits. Studies have shown that chronic exposure to these substances reduces biodiversity, compromises the integrity of food chains, and disrupts fundamental ecological processes such as pollination, decomposition, and nutrient recycling (Goulson, 2013; Pimentel et al., 1992). These effects can have long-term impacts on the resilience of ecosystems to environmental change.

Even when used at low doses, synthetic pesticides can have significant impacts on birds (Li et al., 2020). Recent studies have shown that these insecticides also have harmful effects on non-target invertebrate species. These invertebrates make up a substantial part of the diet of many bird species during the breeding season and are essential for the diet of their offspring (Hallmann et al., 2014).

For frogs, neonicotinoids are an important source of contamination, which comes from agricultural runoff, and are known to affect survival, behaviour and development (Bouffard, 2021). When frogs are exposed to high concentrations through ingestion or skin contact, these pesticides can cause effects such as nervous disorders, seizures, and even death. At lower doses, neonicotinoids can also cause behavioural alterations, such as decreased foraging activity (Dewald 2024).

Also in agriculture, glyphosate is a non-selective herbicide widely used to control weeds. Although primarily targeting plants, its use can have indirect effects on various ecosystems as a whole. The use of glyphosate has been directly associated with a reduction in the abundance of house sparrows, which has caused a rapid decline of this species (Tassin de Montaigu & Goulson, 2023). In bees, exposure to glyphosate has led to changes in their gut microbiome, making them vulnerable to pathogenic complications (Quandahor et al., 2024). Following the extensive use of glyphosate, this practice has now become a major threat to amphibian populations, given their abundant use worldwide (Boone et al., 2024).

Frogs can be contaminated by neonicotinoids from agricultural runoff, which affects their survival, behavior, and development.

Quebec is not immune to the impacts of intensive agriculture on biodiversity loss. In addition to this intensive use, field experiments have shown that 95% of insecticides are useless and that a high proportion of fertilizers are superfluous (Leblanc, 2024). These results, obtained from field trials conducted at 84 sites in Quebec, showed that there was no difference in yield between pesticide-coated seed and regular seed. In addition, less than 5% of the land surveyed had enough insect pests to warrant the use of a pesticide (Labrie et al. 2020). Following these revelations, a committee looked into this abusive situation in the management of chemical pesticides in Quebec, which recommended the adoption of "a precautionary principle in the registration and use of pesticides in agriculture" (Committee on Agriculture, Fisheries, Energy and Natural Resources, 2020).

To reduce these harmful impacts on the environment, several alternative sustainable control measures can be considered, including promoting the use of biological insecticides, such as the use of indigenous isolates of B. bassiana to control the Colorado potato beetle. In addition, the use of Bti is one of the alternative strategies limiting the loss of biodiversity, due to its limited impact on environmental ecosystems. In the following sections, a more in-depth description of Bti is presented, in order to highlight the effects of this biopesticide on the different faunal strata as well as the mitigation measures put in place during its application in the different aquatic environments.

Use of pesticides in agricultural environments.

ANNUAL REPORT ON PESTICIDE USE IN QUEBEC

According to the latest available figures, the annual pesticide use balance in Quebec is **5,000,000 kg** of active ingredients (Pesticide Sales Report, MELCCFP, 2022).

The use of *Bacillus thuringiensis* var. kurstaki (Btk) in forest pest control programs, such as the spruce budworm, accounts for **200,000 kg.**
The total balance of use of Bti for all municipal and other programs accounts for only **1500 kg** , or 0.03% of the annual total, while Bti is by far **the least toxic pesticide.**

This difference in toxicity can be quantified by the average lethal dose (LD50), which measures the amount of substance needed to kill 50% of a population of test organisms. For Bti, studies show that the LD50 is approximately >10,000 mg/kg body weight. This means that a very large amount of Bti is required to kill non-target organisms, making it extremely safe (Reardon et al. 2010).

On the other hand, for chemical pesticides such as pyrethroids, the LD50 is much lower. For example, the LD50 for permethrin (a pyrethroid, commonly used for mosquito control in Canada and elsewhere) is approximately 0.003 mg/kg body weight (Alonso et al. 2001). This shows that it takes far less chemical pesticide to cause lethal effects, making these products much more toxic to non-target wildlife.

Thus, the differences in toxicity are obvious, with Bti being **hundreds or thousands of times less toxic** to non-target wildlife than chemical insecticides.

The SAgE pesticide tool, provided by the Government of Quebec, allows pesticide users to make informed choices. It shows that Bti-based products have by far the most responsible technical data sheets, unlike chemical pesticides which have less interesting health risk indices (SRIs) and environmental risk indices (IREs). (SAgE pesticides, 2025).

Use of pesticides in agricultural settings.

BACILLUS THURINGIENSIS ISRAELENSIS (BTI) : HERE AND ELSEWHERE

Bti is a gram-positive bacterial microorganism found naturally in all soils, water, air and plant foliage. It is used worldwide as a biopesticide, especially in mosquito control. Its effectiveness relies on the production of specific toxins that target only the digestive cells of bloodsucking insect larvae (which feed on blood) while being non-harmful to other organisms, including humans.

Bti-based larvicides are globally established by governing authorities as the preferred alternative to chemical insecticides in mosquito control (World Health, 2020).

In Europe, more than 100 million people are receiving treatment with Bti since the authorities switched from chemical larvicides to Bti. It should be noted that, on the European side, Bti work is authorized in protected areas (such as areas listed in the European Natura 2000 inventory), while in Quebec, protected areas (parks, reserves) are excluded from any treatment (Lewis et al., 2016).

In Canada, there are approximately 40 registered biopesticides based on B. thuringiensis. Health Canada's Pest Management Regulatory Agency (PMRA) granted registration for the sale and use of Btk in 1962, which is the most widely used variety to date, particularly in forest pest control programs such as the spruce budworm. As for the Bti strain, which is used against biting diptera (mosquitoes and small black flies), it has been approved since 1982.

Granular formulation of Bti.

The biolarvicide Bti is an eco-friendly solution that is non-toxic to humans and animals and breaks down quickly in the environment.

In the early 1980s, Quebec was a true pioneer in adopting responsible choices to acquire biological control tools against insect pests (Btk) and biting insects (Bti). Since the arrival of West Nile virus in Canada in 2001, Bti has also been used in the prevention of mosquito-borne diseases as it is an environmentally friendly solution that is non-toxic to humans and animals and degrades rapidly in the environment (Glare & O'Callaghan, 1998; World Health, 2020). It does not have a significant impact on the feeding habits of other animal species (Duchet et al., 2018; Strasburg & Boone, 2021; Timmermann & Becker, 2017).

This biolarvicide is applied to standing or running water, i.e., where mosquitoes and black flies lay their eggs, an approach that is consistent with ecosystem-based management principles. The fight against biting insects, using biological larvicides, shows a collective sensitivity to the preservation of natural environments and contributes to achieving a better balance between the actions of nature and those of human beings. Bti provides a better quality of life for populations affected by these insects (Ferreira & Silva-Filha, 2013; Lacey, 2007).

MODE OF ACTION

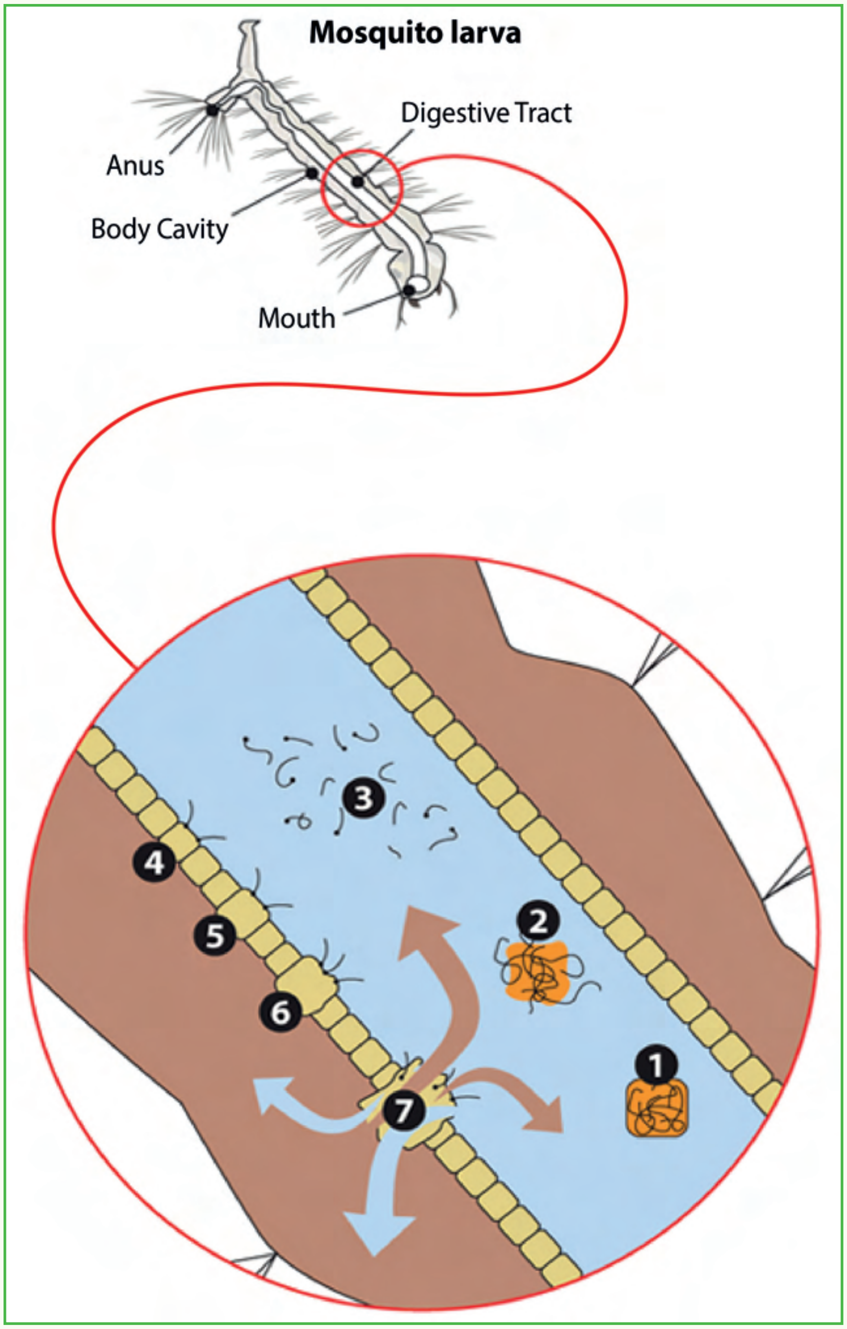
During the sporulation stage of its life cycle, Bti produces a crystallized protein (Andrews et al. 1987; Hannay, 1953), which is toxic only to bloodsucking mosquito and black fly larvae when used at standard dosages (Bulla et al., 1977; Höfte & Whiteley, 1989; Lynch & Baumann, 1985).

The microscopic crystals are ingested by the larvae of these two groups of insects when they feed (Jaquet et al., 1987). The crystals dissolve and transform into toxic protein molecules that destroy the alkaline digestive tract of these Bti-sensitive insects (Schnepf et al., 1998).

The majority of micro and macroinvertebrates, amphibians, fish, reptiles, birds, and of mammals do not have the conditions to release toxins, due to their acidic digestive tract.

1. Bti crystals dissolve in the alkaline fluid of the digestive tract.
2. Long chains of proteins are released.
3. Protein chains are severed by enzymes.
4. The segments, which are toxic to cells in the lining of the digestive tract, attach to these cells.
5. Under the effect of toxins, the cells begin to swell.
6. The cells continue to swell and weaken.
7. Eventually, the affected cells burst causing perforation of the digestive tract, which causes the movement of the digestive juice to the body cavity and a reverse movement of the insect's blood.

The bursting of the digestive tract causes the insect to die.



SAFETY OF BTI

Bti has been permitted in Canada since 1982 and has undergone full and partial re-evaluations on several occasions, including in 2008, 2010 and 2018. Bti products are also being re-evaluated in Europe, the United States and are commonly used in mosquito and black fly population control.

Since the beginning of the use of Bti 40 years ago, there has been a large body of literature that has provided a strong scientific consensus on the safety of Bti. 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) have not demonstrated any direct or indirect impact of Bti on secondary consumers.

Bti only becomes toxic once it reaches the stomach of mosquito or black fly larvae. Therefore, Bti has no effect on other insects such as the honeybee, nor on fish, birds, or mammals (Health Canada).

To be toxic, the crystal must be ingested and the target organism must have a highly alkaline pH digestive tract, enzymes capable of releasing toxic molecules and finally, cell receptors compatible with toxins (Schnepf et al., 1998). It is important to emphasize that the activity of the larvicide comes exclusively from the crystal structure produced during the life cycle of the bacterium. It is also important to know that studies, both in the field and in the laboratory, are carried out with the complete formulation (including additives) and that the effects are documented on the entire formulation. Registration assesses the extent of the potential environmental impact of the active ingredient and additives. It is therefore all the ingredients, contained in Bti-based products, that are evaluated by government agencies and during scientific studies. Note that the liquid formulation of Bti is aqueous and therefore consists mainly of water, whereas the granular formulation is made on a food-grade cracked corn substrate.

The safety of Bti and the safety margins for recommended operational doses indicate that Bti is safe for use in micro- and macro-invertebrates, amphibians, fish, birds and mammals (World Health, 2020).

In 2018, Environment and Climate Change Canada (ECCC) and Health Canada published a re-evaluation of larvicides as part of the Science-Based Risk Assessment Procedure for Regulated Micro-organisms. As with previous evaluations, this one combines all Bt varieties. It states: "Despite the ubiquity and extensive use of various subspecies of B. thuringiensis, there are no known population-level adverse effects on target species in the ecosystems where they are used, and no adverse effects on non-target terrestrial or aquatic plants, vertebrates, or invertebrates. B. thuringiensis is not entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity. (Final Screening Assessment for *Bacillus thuringiensis* strain ATCC 13367 - Canada.ca).

Persistence: Toxins produced by *Bacillus thuringiensis* can sometimes persist in soils for several months. In contrast, typical half-lives of *Bacillus thuringiensis* products are 0.5 to 4 days on foliage. The spores produced by this microorganism may persist in the environment, but they are not toxic.

BTI AT A GLANCE

1. The harmless nature of Bti is based on a strong global scientific consensus established over nearly 40 years (Glare & O'Callaghan, 1998; Lacoursière, 2004; Lagadic et al., 2016).
2. The WHO, as well as all government authorities in all countries where the product is available, define Bti as a safe and suitable product for the control of biting insects (World Health, 2020).
3. The efforts to protect our rivers, carried out in recent decades, have allowed the recolonization by these populations of aquatic insects that are reputed to be sensitive and which are excellent bio-indicators of the quality of our waterways (Desquilbet et al., 2020).
4. The control of biting insects using biological larvicides allows millions of Canadians to restrict the use of chemical pesticides and insect repellents.

The biological larvicide Bti specifically targets mosquito and black fly larvae by disrupting their digestive system, without affecting other beneficial organisms in the ecosystem.

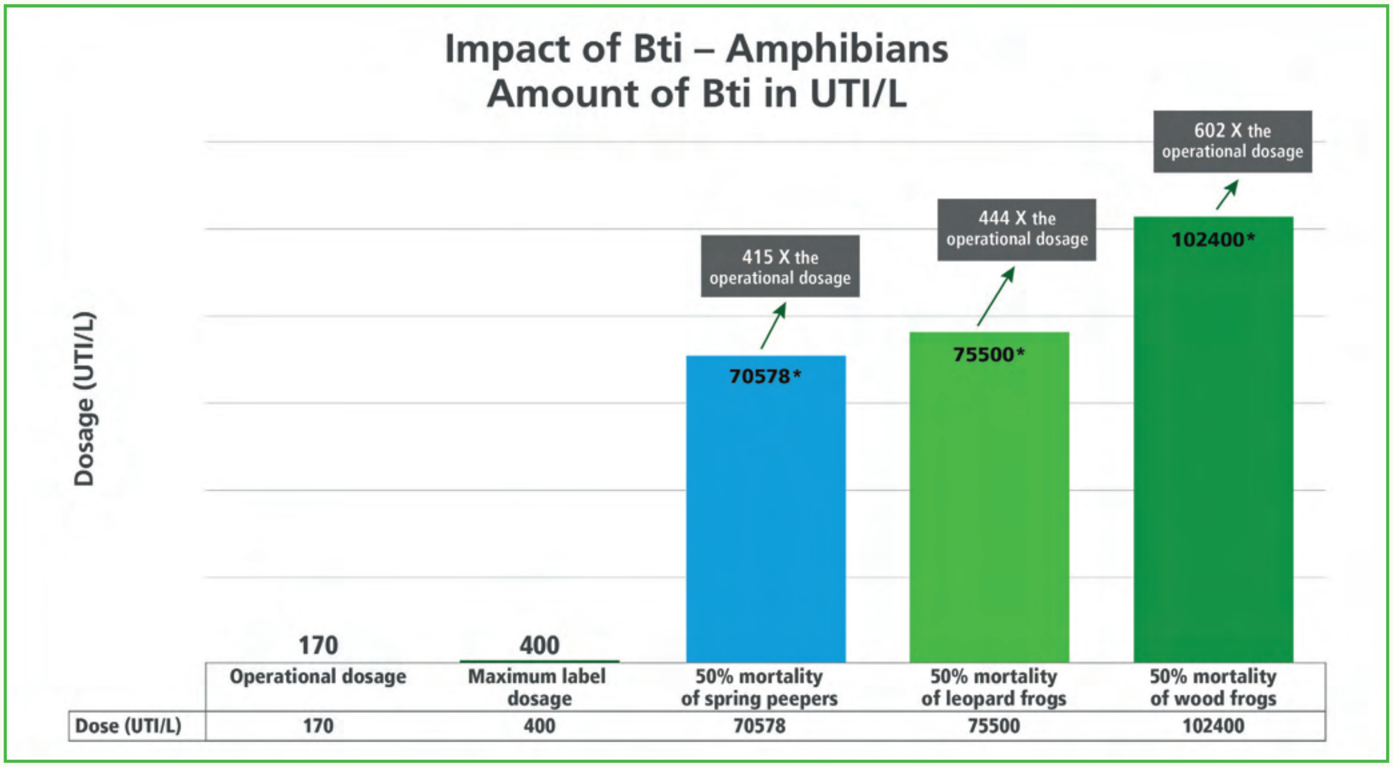
EFFECTS ON AMPHIBIANS

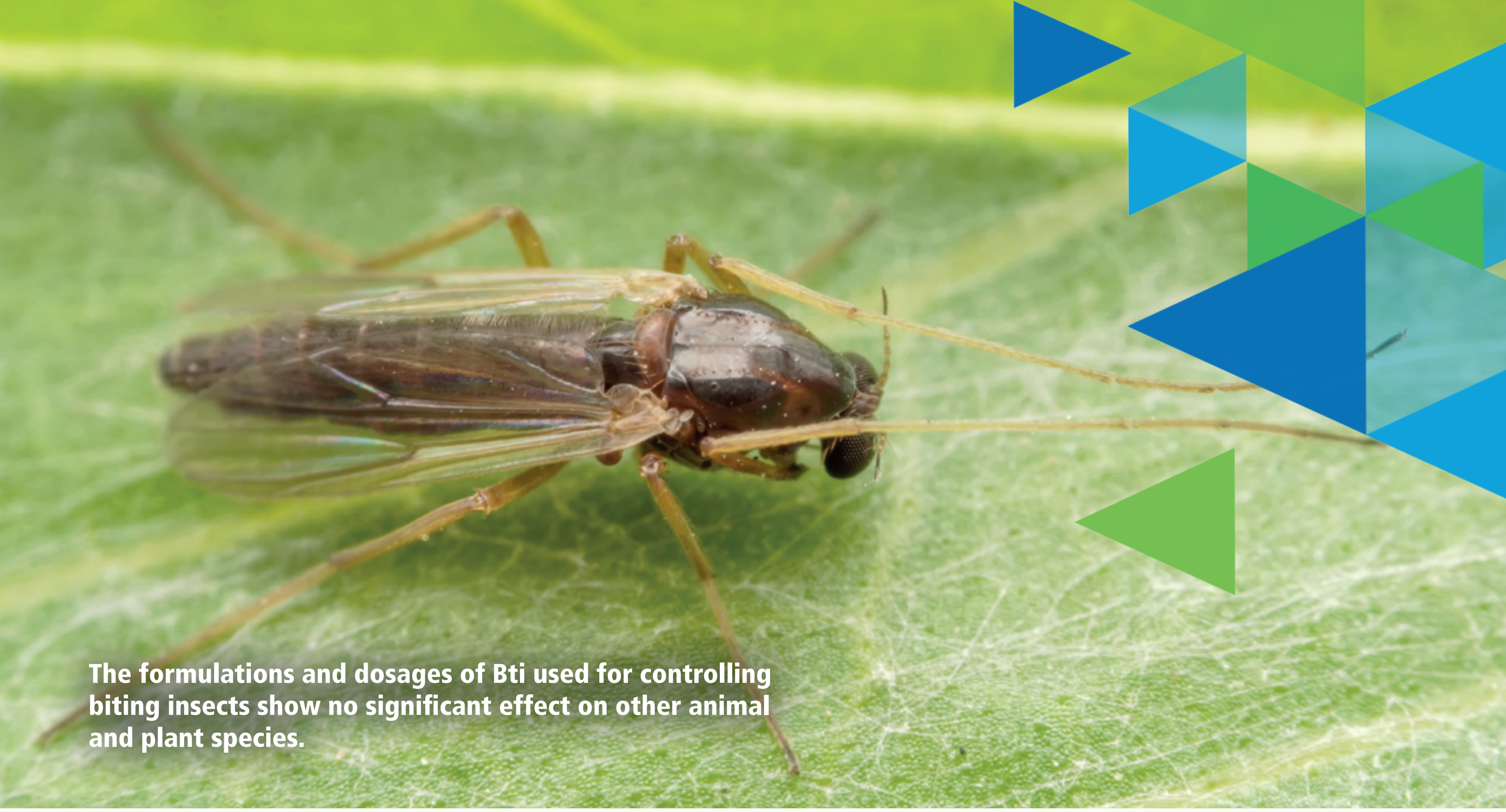
Previously, studies reported no direct or indirect effects of Bti on amphibians (Boisvert & Lacoursiere, 2004; Glare & O'Callaghan, 1998). In 2015, a laboratory study from a research group in Argentina raised the possible impacts that overdose can have on amphibians (Lajmanovich et al., 2015). Since then, other articles, including those published in 2018 and 2019 in Germany, have contradicted the results of this study, recording no mortality and no impact on amphibian development (Allgeier et al., 2018; Schweizer et al., 2019).

In this sense, a two-year study conducted in Minnesota in the laboratory and field, as well as another conducted in India in 2011, came to the same conclusions (Johnson & Johnson, 2001; Tiwari et al., 2011).

In addition, a study conducted in Trois-Rivières on native frogs showed no effect on the development of tadpoles feeding on the corpses of mosquito larvae treated with Bti (Raymond Leclair, 1988).

In 2021, a Quebec study commissioned by the Ministry of Forests, Wildlife and Parks came to the same conclusions, not demonstrating a significant biological effect (Gutierrez-Villagomez et al., 2021).
Recently, a study conducted by the University of Ottawa for the City of Ottawa demonstrated the dosages needed to kill Canadian frog species. The results are presented in the graph below, compared to the assays used during larval population control operations in wetlands (Empey, 2022).





The formulations and dosages of Bti used for controlling biting insects show no significant effect on other animal and plant species.

EFFECTS ON CHIRONOMIDS

Despite their relative phylogenetic proximity to mosquitoes, chironomids are about 425 times less sensitive to Bti than mosquitoes. The present study shows, once again, that chironomid abundance is not affected by the presence of Bti. In some cases, chironomid larvae are even significantly more abundant in the treated area (cf. Guérande, Mornac-sur-Seudre and Budos stations). This observation, already carried out during previous studies in Morbihanou in the Bouches-du-Rhône (studies carried out by scientists from different institutes), is probably not the result of chance. Indeed, chironomid larvae have “eater-eaten” relationships comparable to those of mosquito larvae. When mosquito larvae are eliminated following treatments with Vectobac, a Bti-based larvicide, their ecological niche left vacant can potentially be occupied by chironomid larvae. As a result, the biomass of food available to predators would vary little. The absence of direct toxic effects in taxa potentially sensitive to Bti therefore makes it very unlikely that indirect effects cascade via food chains are hypothesized. (Long-term evaluation of the unintended effects of mosquito control in the EID-Atlantic’s areas of intervention; INRA Ecotoxicology and Quality of Aquatic Environments Team, December 2014).

Studies show that biting insect control programs that use an operational assay, according to the application standards established by government and industrial authorities, do not affect the density of chironomids in the wild (Duchet et al., 2015). Another six-year study in Sweden concluded that the application of Bti in the wild did not cause any major direct negative effects on chironomid production (Lundström et al., 2010).

A field study conducted by researchers at the University of Ottawa is evaluating the possible effects of Bti on chironomids. The report submitted to the City of Ottawa indicates that there has been no decrease in density or biodiversity in the chironoid populations surveyed. The findings demonstrate that it is not possible to associate the use of Bti as a determinant of the emergence rate of non-target insects (Epp, 2020).

EFFECTS ON AERIAL INSECTIVORES

A large body of literature confirms that mosquitoes are not target prey for both insectivorous birds and bats (Beck et al. 2013; Fang, 2010). Studies on the analysis of stomach contents show that the diet of aerial predators (insectivorous birds, bats) relies on only 1% of mosquitoes, regardless of the high density of mosquitoes available (Boukhemza-Zemmouri et al., 2013; Mengelkoch et al., 2004). The energy gain is simply too small to allow predators to feed on these small insects (Kale 1968; Orłowski & Karg, 2011). Moreover, the echolocation of bats does not allow the detection of such small prey, which corroborates studies on the analysis of stomach contents (Wetzler & Boyles, 2018).

Despite the small size of its beak, Eastern Whip-poor-will is able to open it to a very large range, allowing it to hunt in mid-flight and feed on moths, beetles, and other large flying insects (Nature Conservancy of Canada 2025).

A recent study in Nova Scotia of 3 swallow species concluded that insect abundance has no effect on brood survival and chick weight (Imlay et al. 2017). One of the explanations put forward by the study proposes that variability between regions could have a greater influence on the diet of insectivorous birds.

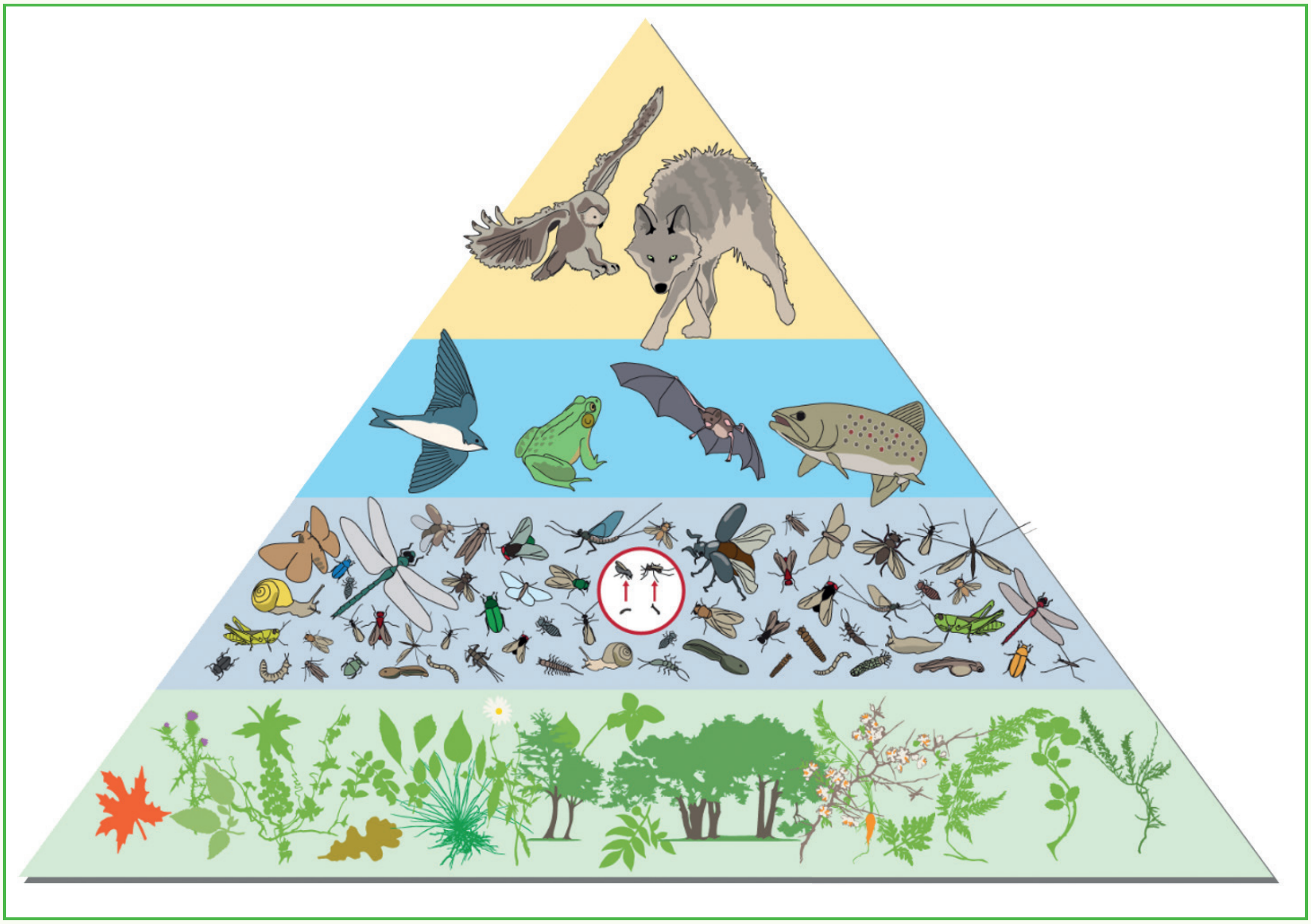
In France, research raises doubts about the likely impact of Bti treatment on non-target wildlife (Poulin et al., 2010). This study is now disputed by several researchers who denounce, among other things, the history of treatments using chemical pesticides, the ecological heterogeneity initially chosen between control and treated areas and the lack of studies on the availability of prey, on which the conclusion is hypothetically based. These researchers published a study on the impacts of routine Bti treatments on the availability of flying insects as prey for aerial predators (Lagadic et al., 2014; Timmermann & Becker, 2017).

It is important to make certain distinctions with respect to the studies carried out in the Camargue, describing potential negative impacts on avian fauna. These studies are not representative of the control operations carried out in Quebec, since these environments are heterogeneous. The Camargue Regional Natural Park has nearly 10,000 ha of networks of ponds and marshes and extends over three French municipalities. In Quebec, control operations are carried out on very small areas, consisting mainly of temporary stagnant bodies of water. In addition, the studies in the Camargue are conducted at higher doses compared to the operational assays used in Quebec, which far exceed the prescription authorized by the PMRA in Canada. Another major distinction is that the marshes of the Camargue are subject to dozens of treatments per year (30 to 50 treatments), whereas here the majority of water pools are treated only once a year or at most a dozen applications in certain more productive roosts.

Numerous studies show that small insects such as mosquitoes are a marginal and incidental part of the diet of insectivorous birds and bats.

FOOD WEB

The diet of insectivorous predators is composed of a vast inventory of aquatic insects. The reduction in the biomass of available mosquito larvae and black flies does not cause significant additional disturbances in habitat components. It is important to consider the full range of ecological factors to understand the many interactions within insect communities. In wetlands, the food web can be influenced by habitat ecological composition, colonization cycles, physicochemical parameters, and predator-prey interactions (Batzer & Wissinger 1996). The figure below highlights the diversity of insects that we can find in an aquatic ecosystem.



Example of a food web that includes mosquitoes and black flies (highlighted in the red circle).

Entomological sampling conducted over more than 40 years in Quebec shows an increase in mosquito and black fly (simulium) populations.

The aquatic biomass generated by these insects is already biologically temporary, since they move into the terrestrial stage in their life cycle and do not constitute potential prey for predatory species throughout their lives. Thus, the composition of the aquatic biomass of these insects causes a decrease in the resource at a certain point in their life cycle.

In the case of biting insect control, the reduction in biomass is only partial and temporary since treatments are only carried out when the larvae have reached a certain stage of development and are about to move on to their terrestrial life stage. It should also be remembered that integrated pest management does not aim to exterminate them completely, but rather to reduce their population levels to a tolerable density, so that citizens can enjoy outdoor activities.

Laboratory studies do not allow us to consider all the likely interactions and impacts. Indeed, several studies show that non-target insects are little affected by the use of Bti in media natural (Charbonneau et al., 1994; Duchet et al., 2015; EPP 2020; Lagadic et al., 2016; Liber et al., 1998). 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) have not demonstrated any direct or indirect impact of Bti on secondary consumers.

Despite the decline of several groups of terrestrial insects, aquatic insects have increased by 38% over the past 30 years according to a meta-analysis of 166 long-term studies (Desquilbet et al., 2020).

Entomological sampling conducted for more than 40 years in Quebec shows this increase in mosquito and black fly (blackflies) populations. Thus, the efforts to protect our rivers carried out in recent decades have allowed these populations to recolonize aquatic insects, in particular the small black flies that are reputed to be sensitive and which are excellent bio-indicators of the quality of our waterways.

RESISTANCE

To date, no study conducted in the wild has demonstrated the resistance of any species to Bti. The complexity of the mode of action between the pathogen and the target insect makes it unlikely that an insect will develop resistance to this product. Indeed, this complexity stems from the combined and synergistic action of the four proteins associated with the toxic process of crystals (Höfte & Whiteley, 1989). Although it is theoretically possible to develop resistance to Bti crystals in the field, the probability of such an event occurring is very low (Schnepf et al., 1998).

In Quebec, the same assays have been used for more than 40 years, indicating the absence of resistance. The small number of treatments required allows individuals from untreated areas to mix with exposed populations, thus limiting the development of resistance to this biolarvicide.

In Germany, a mosquito control program using Bti has been in place since 1981. Over the years, an estimated 189 generations of Aedes vexans have been under selection pressure from Bti. A recent study demonstrated that no resistance has been developed in treated sites for 36 years (Becker et al., 2018). Similarly, another study demonstrates the absence of resistance following the exposure of 30 generations of Aedes aegypti to Bti (Carvalho et al., 2018).

In addition, in a laboratory study, resistance to certain toxins was observed. However, no resistance has been observed in mosquito populations found in the wild after several decades of Bti treatment (Tetreau et al., 2013)

The complexity of the interaction between the pathogen and the target insect makes it unlikely for the insect to develop resistance.

The scientific literature shows no significant direct effects of Bti on human health or on mammals, fish, birds, and reptiles in general.

EFFECT OF BTI ON HUMANS

The scientific literature does not demonstrate any significant direct effects of Bti on human health or, more generally, on mammals, fish, birds or reptiles.

Mammals do not possess the physicochemical characteristics to activate the toxin contained in Bti, making it safe for humans (World Health, 2020). In the re-evaluation of the registration of *Bacillus thuringiensis*, the Pest Management Regulatory Agency (PMRA) states that:

"The consumption of treated products cannot be expected to pose a risk to the public, children and infants. The potential for exposure from drinking water is negligible. The low toxicity of *Bacillus thuringiensis* and the demonstration of its safety suggest that human exposure from drinking water does not pose a significant risk. See Appendix 1 for Health Canada's BTI Factsheet.

In addition, no toxic, infectious, or pathogenicity via the oral, inhalation, or intraperitoneal or dermal exposure has not been observed.

It appears that no known toxins or metabolites of B. thuringiensis are endocrine disruptors or have a toxic effect on the immune system. It is important to remember that when registering, Health Canada (PMRA) takes into account the complete list of ingredients (even those protected by trade secrets) for each of the approved formulations.

Human health and ecotoxicity studies are performed on formulations and therefore include the effects of additives or adjuvants in their results. The U.S. Environmental Protection Agency (EPA) has also concluded that dietary exposure to residues of B. thuringiensis is reasonable to expect to 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 (Winegard, 2019).

TRANSMITTED DISEASES BY BITING INSECTS

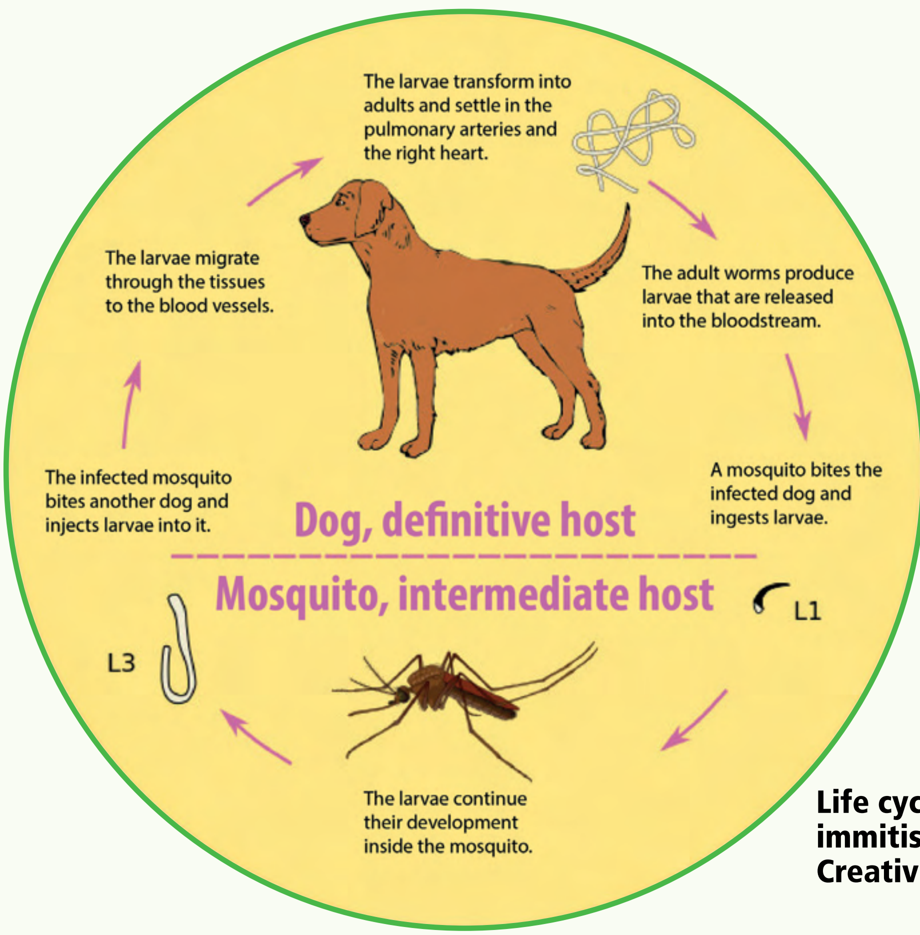
In addition to being harmless to humans, the use of Bti reduces the risk of spreading certain diseases by eliminating their vectors. In fact, the mosquito is the deadliest animal in the world because of the diseases it can transmit as a result of its bite. Globally, mosquitoes cause 1,000,000 deaths per year.

Our pets are not spared from biting insects, as several pathologies can be transmitted to them. Among these diseases, heartworm (heartworm) is particularly noteworthy. It is a parasitosis caused by *Dirofilaria immitis*, a filarial worm that mainly infects the heart and lungs of dogs and cats. This disease, which is widespread in North America, is responsible for the death of many pets if not detected and treated in time.

In horses, two major viral forms of equine encephalitis, namely Eastern Equine Encephalitis (EEE) and Western Equine Encephalitis (WEE), are frequently encountered. Both neurological conditions, caused by mosquito-borne flaviviruses, often lead to severe symptoms, including seizures, impaired coordination, and in many cases, death of the animal.

In Canada, 10,000 human cases of West Nile virus have been diagnosed since its arrival in Canada in 2001.

No less than 63 species of mosquitoes are present in Quebec. A dozen can transmit diseases to humans and the list of diseases they carry continues to grow. In 2024, Ontario and the North American states were hit by fatal cases of eastern equine encephalitis. This virus, transmitted by Culiseta melanura, is one of the deadliest in the world, causing death in more than 30% of those infected. (Health Canada website, modified 2025-02-20)



Life cycle of Dirofilaria immitis (after Anka Friedrich, Creative Commons license).

There has been a significant increase in mosquito-borne diseases in a context of climate change where vector migration will be an important issue in a few years (Ludwig et al. 2019). In Canada, a study on the spatial distribution of the main mosquitoes vectors of West West Nile virus shows that climate change is introducing significant emergence over new areas of the territory (Rosenkrantz, 2022). Temperature increase has a direct effect on the risk of contracting major diseases such as West West Nile virus and could prove to be a significant threat to public health (Figueroa et al., 2020; Reisen et al., 2006; Wiese et al., 2019).

In such a context, active and well-coordinated entomological surveillance is crucial to anticipate and manage the risks associated with biting insects and protect public health. Collective mosquito nuisance management programs include a surveillance component that allows municipalities to better protect their residents, manage environmental and public health risks, and maintain attractive and safe living spaces.

Data collected through entomological surveillance can be used to educate residents about the risks associated with insect vectors and the preventive measures they can take. This helps build an informed and proactive community.

To prevent contamination by mosquitoes, personal protective measures are also important:

- Repair mosquito nets at home.
- Eliminate mosquitoes before going to sleep.
- Wear long clothes in the evening and use a repellent.
- Eliminate artificial roosts where mosquitoes lay their eggs. The environments conducive to their proliferation are those that accumulate stagnant water: tarps, clogged gutters, undrained boats, unstarted pools, etc.
- Establish a collective programme for the integrated management of mosquito nuisances

Climate change promotes the spread of mosquito-borne diseases, with a geographic expansion of vectors, notably in Canada for the West Nile virus.

REGULATORY FRAMEWORK

Federal

The registration of Bti-based biopesticides is regulated at the federal level by Health Canada's Pest Management Regulatory Agency (PMRA). The risk assessment is based on scientific data at both the active ingredient and the finished product level. For example, risks to non-target insects are assessed in relation to Bti, but also in relation to all the by-products that are contained in the formulations.

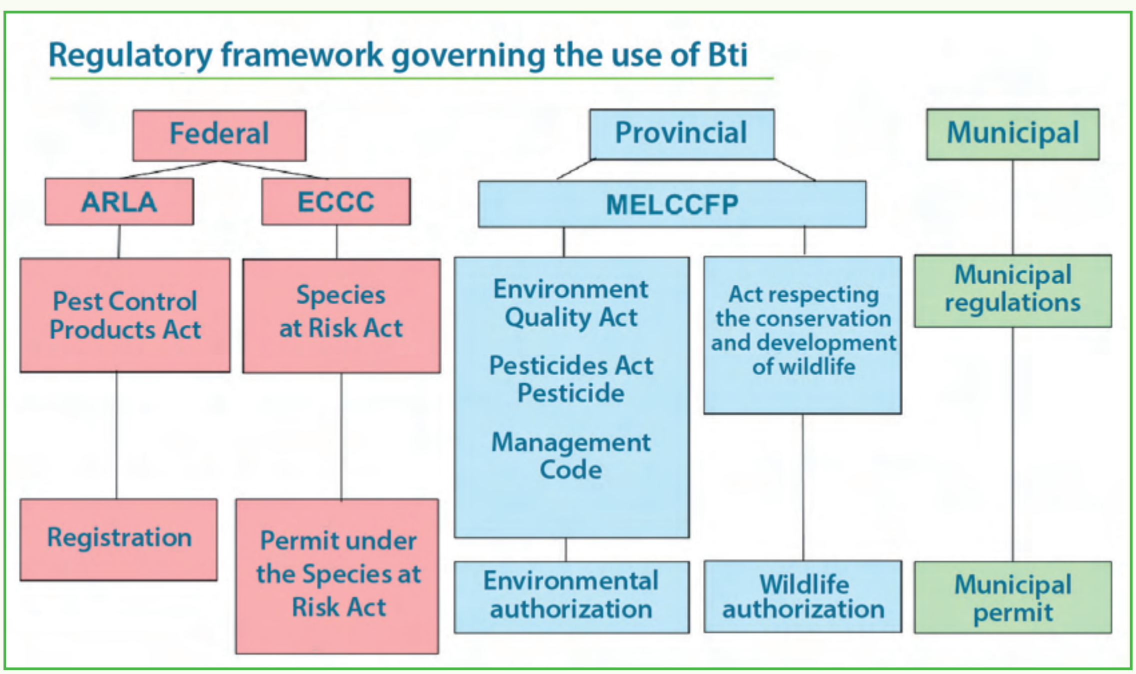
On federal lands, Bti users must also check for species at risk and apply for a Species at Risk Act (SARA) permit from Environment and Climate Change Canada (ECCC).

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

Provincial

Although Bti is a biopesticide and its safety has been demonstrated for many years, biting insect control programs are strictly supervised by the Ministry, being subject to the ministerial authorization process (EQA Art.22) and wildlife advisory. The Department therefore takes into account several aspects such as the characteristics of the environment, the nature of the planned activity, the economic and social consequences, and the impact of the activity on the conservation of wildlife and its habitat. Finally, when the treatments are located in a regulated wildlife habitat such as an aquatic bird concentration area (ACOA), a wildlife authorization must also be requested under the Act respecting the conservation and development of wildlife. This cautious approach of the MELCCFP is unique. It should be remembered that in Europe, biological larvicides such as Bti are used in protected areas.

In addition, a company that wishes to carry out treatments using Bti must first obtain a specific permit from the Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP). Second, the employees performing the treatments must obtain a pesticide user certification, specializing in the control of biting insects.



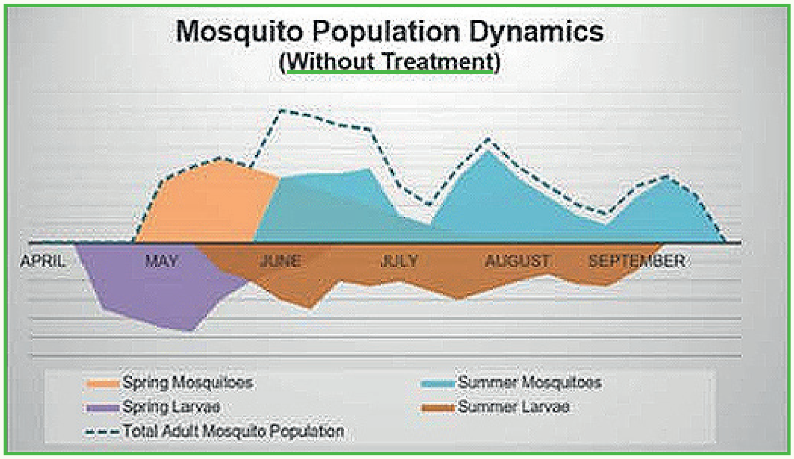
Mosquito larvae develop in stagnant water, while black fly larvae develop in flowing water.

USE AND APPLICATION OF BTI IN CANADA

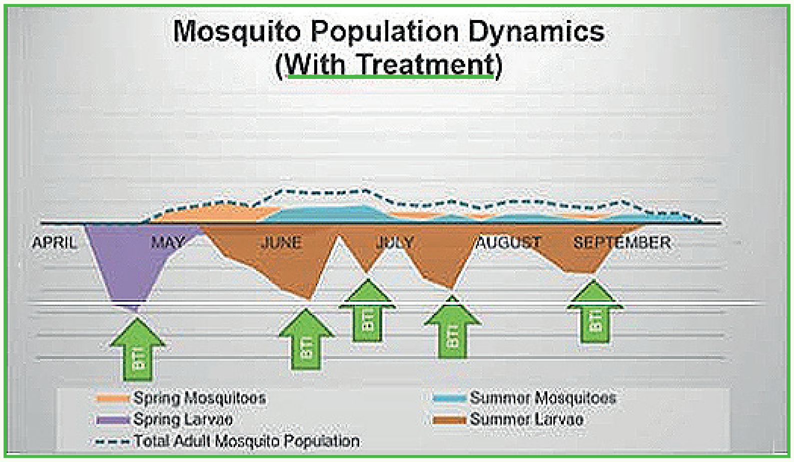
The control of biting insects using a biological larvicide such as Bti is already an innovative practice since the operation relies on the use of a biopesticide. Companies and/or organizations follow an integrated pest management plan in their control program. To better understand the context in which the operations take place, here is a summary of the methodology commonly used.

There are two types of control programs depending on the nuisance observed in the municipality: the treatment of mosquito populations (Culicidae) and the treatment of small black fly (Simulidae) populations. Mosquito larvae thrive in stagnant water, while black fly larvae thrive in waterways.

MOSQUITOES TREATMENT



General cycle of mosquito larval and adult populations in eastern Canada **without Bti treatment.**



General cycle of mosquito larval and adult populations in eastern Canada **with Bti treatment.**

During mosquito population control operations, the ideal time for treatment is when the majority of mosquito larvae have reached developmental stages 3 and 4, i.e. just before pupation. The first spring mosquito treatment is predictable and synchronized with snowmelt and spring freshet.

Subsequent treatments are carried out according to the hatching of the larvae. The emergence of summer biting species is highly dependent on rainfall. From mid-May, heavy rainfall can allow the emergence of so-called summer species. Aedes vexans is the most abundant species. Some of the deposits that have been refilled with water may be treated several times. Field survey teams are trained in mosquito species recognition and are supported by entomologists.

The main species targeted by the control are those of the Aedes-Ochlerotatus group, which includes the majority of biting species. The following graph shows the evolution of spring and summer mosquito populations, without treatment, and with Bti treatment.

It is important to note that there is no extermination of mosquito populations and that there is always a residual population. The goal of biting insect control is to reduce mosquito populations to a level acceptable to surrounding citizens.

TREATMENT OF BLACK FLIES

For black fly populations, the position and number of treatment points may change depending on the location of the larvae. Since the treatments are carried out in running water, the effective scope of the product varies greatly depending on the hydrology and physico-chemical conditions of the watercourse. The flow of small streams is highly variable throughout the season (snowmelt, rainfall or drought, beaver dam) and this changes the number and distribution of treatment points. While some streams produce only one larval generation in the spring, other streams may be treated up to ten times during the season.

BEFORE AND AFTER TREATMENT

Regardless of the type of treatment envisaged, sampling of the roosts always precedes the spreading work. Treatments are only carried out if there are larvae of species that bite humans. The prospection of the various habitats makes it possible to carry out the controls at the appropriate time. There is no preventive treatment.

The quality control of treatments is carried out in several ways. The effectiveness of applications is assessed by larval mortality 24 to 48 hours after larvicide applications. Then, the resulting nuisance is estimated using standard entomological net testing (short duration) and by the use of traps installed over periods of 12 hours or more (long duration).

AERIAL SPRAYING

The products used for the treatment of mosquito larvae are found in liquid or granular form. In aerial applications, the granular formulation has several advantages. The pellets are made of cracked corn kernels that do not contain any residues that could drift or solvents that could evaporate into the atmosphere. Winds of less than 10 knots have very little control over granular spreading. The risks of abuses are therefore practically nil. The granules penetrate vegetation and reach mosquito ponds.

The air route (drones and helicopters) is used during control operations in larger gîtes or those that are difficult to access by ground technicians or for sites requiring little physical disturbance. Aerial treatments are essential in spring and during heavy re-wetting (heavy rain not absorbed by the soil).

Aerial spraying is very accurate thanks to the use of a D-GPS guidance system. The spreading equipment used is connected to on-board computers that adjust the flow rate according to the actual ground speeds, thus ensuring an exact and uniform dosage in all flight conditions.

In addition, this work is overseen by Transport Canada, as mentioned in the regulatory framework section.

MINIMAL AND TARGETED TREATMENT AREA

The total treatment area needed to protect an entire municipality can be as small as a few hectares. Treatment sites or intervention areas represent a small fraction, often less than 1% of the municipal territory.

The treatment area takes into account the species present and their displacement capacity or flight radius. Females of most species of mosquitoes and black flies require a blood meal 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 found, the presence of migration corridors, winds and other meteorological parameters.

According to the scientific literature, mosquitoes can easily fly up to several kilometers from their emergence site, but 2 km is the average for several species. Black flies have an even greater range, the average is between 4 and 6 km.

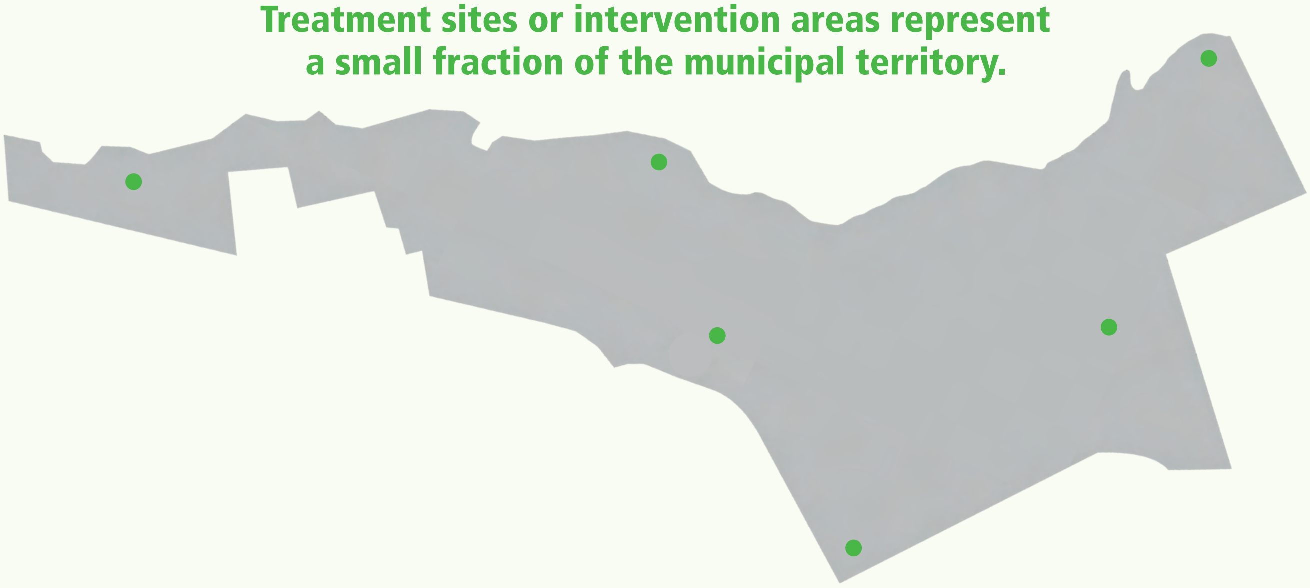
The development of the intervention limit is complex and unique for each project. A 2 km limit of intervention around the protected area for mosquito control is usually sufficient to maintain a minimum 80% decrease in nuisance. It is also necessary to keep

Migration corridors that promote the movement of biting insects, such as lakes between two mountain ranges or hydroelectric lines. These corridors lead to migrations that can lead to new spawning in treated water bodies and streams, from which mosquitoes and black flies will re-emerge if they are not treated throughout the summer.

Bti is applied directly to wetlands and streams where it selectively attacks mosquito and black fly larvae. This methodology considerably reduces the impact on the territory, since the larvae are concentrated in specific places where they are then vulnerable. Targeted larval treatment therefore makes it possible to intervene in very small portions of the territory rather than waiting for them to pass to the adult stages where they spread throughout the territory. Once these insects are dispersed in the air, efforts to control them become out of reach. The fact that we do not intervene at the source of the problem means that we have to intervene on nearly 100% of the territory afterwards, often to the detriment of chemical alternatives.

Fumigation programs are still used today at the municipal level in other provinces of Canada, in the United States and in several other countries. Quebec's position in biological control of biting insects is undoubtedly the most enviable to the world.

Treatment sites or intervention areas represent a small fraction of the municipal territory.



Insect monitoring helps detect disease risks, plan preventive actions, and protect the population.

ENTOMOLOGICAL SURVEILLANCE PROGRAM

For health authorities, entomological surveillance makes it possible to quickly identify threats from disease-carrying insects, plan effective preventive interventions, protect the population from epidemics, and provide crucial data for research and public health policy-making. It also helps to raise public awareness and promote preventive behaviour. In a context of climate change where vector migration and the rise of mosquito-borne diseases are now affecting our latitudes, entomological surveillance programs are the first line of defense to be deployed (Ludwig et al. 2019).

The programs include capture protocols, species identification of collected specimens and molecular analyses of pathogens. Catches are generally made using trapping poles, often equipped with a small vacuum cleaner and using bait (carbon dioxide (CO_2), lactic acid, octenol or other decoys).

As part of a nuisance control program, the analysis of collections also makes it possible to determine the origin of biting insects and to direct larvicidal interventions towards sites of specific development. It is also possible to use traps to reduce a residual or occasional nuisance by the following mosquitoes, for example, the exclusion of certain properties or protected areas. Traps placed in a tight line can have a barrier effect and restrict the horizontal migration of mosquitoes. Mosquito traps have a very limited radius of attraction. According to the literature, traps must be set at a distance of 5m to 15m to be effective (Brown et al., 2008). However, there are no traps targeting small black fly populations. The “Alternative Control Methods” section described later in this document elaborates further on the effectiveness of traps for nuisance reduction.

SOCIAL ACCEPTABILITY

All municipal biting insect control programs are carried out at the request of the citizens of a municipality facing a nuisance problem and are the subject of several consultations. Projects can progress over many years, and go through several stages, before being implemented. The following is an example of the consultative process for implementing these programs: Public presentations, municipal surveys, public tendering process, adoption of the project, posting on tax bills, sharing of an informative press release for citizens, implementation of a mosquito tip line and a citizen query system while communicating scientific updates to municipalities.

The public nature of biological larvicide control programs in municipal settings requires several stages of consultation, clear communication of all aspects of the program, and majority approval.

The results of numerous independent surveys, conducted among thousands of Canadian citizens by recognized polling firms or during consultations conducted by the host municipalities of such a program, confirm the adherence of citizens to programs for the control of biting insects using biological larvicides. On average:

- **76% of citizens** agree with the measures put in place.
- **80% of respondents** consider the interventions to be “fairly effective” or “very effective.”
- **74%** consider the cost-benefit ratio of the services to be “good” or “very good.”
- **73% of citizens** state that they no longer use other products to protect themselves against biting insects.
- **89% of citizens** surveyed mention that the most important summer activity for them is access to their yard or outdoor balcony, allowing them to move around, socialize, or relax.

Surveys of thousands of Canadians show that citizens support the use of biological larvicides to control biting insects.


The control program using biological larvicides supports urban development and attracts new families.

BENEFITS OF BITING INSECT CONTROL

The nuisance caused by biting insects prevents many citizens from enjoying the outdoors. In some cases, they can be responsible for allergic reactions or the transmission of much more serious diseases (arboviruses).

Controlling mosquito and black fly larval populations in aquatic environments is the most environmentally friendly and effective way to reduce nuisance by targeting the source of the problem. The control program using biological larvicides fits perfectly into a family policy that focuses on quality of life and outdoor activities. This is a sound management of resources and contributes to the protection of the territory's wetlands by allowing people to live nearby without suffering from discomfort. It is a great development tool for many cities and also a very good argument to attract new families to the places inflicted.

Such responsible control also makes it possible to retain visitors and attract summer visitors (campgrounds and others), thus maximizing the economic benefits of recreational tourism activities. It also makes it possible to develop and take advantage of the full potential of investments in municipal recreational infrastructure. In addition, this program allows citizens to limit their expenses related to the purchase of sprays, insecticides, citronella or mosquito net shelters. The use of these products does not really offer the desired effect and is often undesirable.

Increased family activities, full accessibility to summer activities

- Increase in recreational and tourism activities
- Increase in property market values
- Better use of municipal recreational infrastructure
- Leveraging the richness of the environment and natural environments
- Significantly improved quality of life for citizens and visitors
- Hiring and local economic activities
- Reduced risk of disease transmission by vector species
- Decreased allergic reactions and stress caused by severe nuisance
- Reduction in the use of chemicals (diffusers and insect repellents)
- Reduction of sedentary lifestyle and social compartmentalization

Controlling mosquito and black fly larval populations in aquatic environments is the most environmentally friendly and effective way to reduce the nuisance caused by these insects by intervening at the very source of the problem.

The costs associated with implementing a control program using biological larvicides are comparable, and often even lower, to the expenses of each person in the purchase of repellent products.

ALTERNATIVE CONTROL METHODS

We often hear about alternative methods to carry out mosquito control. Among these methods, the best known is the use of mosquito traps or terminals.

Several models of mosquito traps using different attractants are available on the global market. However, with reference to subsection 2 of the Pest Control Products Regulations (PCPR), it can be seen that devices or attractants (such as octenol and CO2) used as a means of direct control by destruction, attraction or repellent are subject to registration with the Pest Management Regulatory Agency (PMRA) of Canada. However, currently, very few devices and attractants are registered in Canada. As part of a nuisance control program, they can only be used under a research authorization issued by the PMRA (research permit). The PMRA's top priority is to protect the health and safety of Canadians and the environment. Before a product is permitted for use in Canada, it must undergo a rigorous scientific evaluation process that provides reasonable certainty that it will be safe when used according to label directions.

It is important to know that mosquito traps have a limited radius of attraction. According to the literature, traps must be installed in a tight barrier, i.e. at distances of 5m at 15m to be effective (Brown et al., 2008).

A control approach based solely on their use to protect municipalities or other large areas is unrealistic. At the municipal level, the number of traps needed to protect citizens and allow outdoor activities to be enjoyed would be too many important. Acquisition and operating costs would be out of reach. In addition, these traps capture a good number of other non-target insects more than 40% of chironomids, moths, etc. which are a component of the diet of some predators. Conversely, programs using Bti are selective for biting insects. It should also be noted that there are no traps targeting the populations of small black flies that are easily controllable in programs using Bti.

However, these devices can play an important complementary role in the context of integrated nuisance management programmes. The multi-pronged approach of these programs makes it possible to target larval breeding sites using biological larvicides and to use a network of traps to reduce a localized nuisance. This complementarity is essential in the vicinity of exclusion zones for certain properties or protected areas. Traps placed in a tight line can then have a barrier effect and restrict the horizontal migration of mosquitoes.

Other control alternatives put forward include the contribution of predators (e.g., bats, birds, fish), the use of plant extracts, entomopathogenic fungi, male mosquitoes (irradiated, genetically modified or bacteria-carrier), amino acids, etc. However, most of these alternatives are either still at the research stage, ineffective or not applicable to Canadian species.

Of these alternatives mentioned above, it is possible to install nesting boxes for insectivorous birds or bats, but these, contrary to the myths conveyed, feed very little on mosquitoes and even less on black flies. No efficacy has been demonstrated for this method. The use of aquatic predators on a large scale is not realistic given the diversity of breeding environments, but their use in artificial roosts can be effective (e.g. the introduction of fish into water gardens).

It should also be noted that in the absence of a control programme, several undesirable methods may be used by citizens. Indeed, it has been observed that some exterminators offer a chemical treatment against mosquitoes. These treatments should be avoided, since they unfortunately affect the area subject to treatment with certain consequences.

Without a collective integrated nuisance management program, it has been shown that people turn to chemical solutions that are often more harmful to their health and the environment; Insect repellents and individual diffusers. Chemical repellents such as DEET and picaridin make up the vast majority of insect repellents used to protect against mosquito bites. In Quebec alone, more than 20,000 kg of active ingredients used annually end up in the environment and in our drinking water (MELCCFP, 2024). These substances pose risks to human health, especially with prolonged use.

Neurological effects: DEET, while effective in repelling mosquitoes, has been associated with side effects. Studies have shown that DEET can cause neurological effects in humans, particularly with prolonged exposure or high doses. For example, a 2010 study found that DEET could impair neuronal function, especially in children and people with more permeable skin.

It has also been observed that repeated exposure to DEET can lead to symptoms such as seizures and memory impairment. (Swale et al., 2014).

Although picaridin is sometimes considered safer than DEET, it is not risk-free. One study demonstrated that bioaccumulation of picaridin in the environment would affect amphibians (Almeida et al. 2018).

It should be noted that the active ingredients contained in insect repellents and individual diffusers add to the use of chemical pesticides.

Among other choices, the drainage of wetlands, sometimes considered to limit the proliferation of mosquitoes, has disastrous and permanent consequences on our environment. No desirable physical development could lower the level of nuisance sufficiently to improve the quality of life of the citizens concerned.

When the different methods of controlling biting insect populations are presented in a decision matrix, it becomes fairly obvious that the use of Bti is the best way to go.

ASSESSMENT OF ALTERNATIVES

BTI remains the best solution.

🟢 POSITIVE
🔴 NEGATIVE

	DO NOTHING	USE CHEMICAL PESTICIDES	IMPLEMENT PERMANENT DRAINAGE	USE NATURAL PREDATORS	USE TRAPS	USE INSECT REPELLENTS	USE BTI
Effectiveness		🟢🟢🟢	🟢		🟢	🟢	🟢🟢🟢
Environmental impact		🔴🔴🔴	🔴🔴	🟢	🔴	🔴	🔴
Impact on health	🔴	🔴			🟢	🟢	🟢
Total	**-1**	**-1**	**0**	**1**	**1**	**1**	**3**

EDITORIAL TEAM

- **Richard Trudel** Ph.D., Forest Science
- **Richard Vadeboncoeur** B.Sc., entomologie
- **Karolann Trépanier** M.Env., Biology
- **Jean-Simon Bédard** B.Sc. Geomatics
- **Jean-François Houde** B.Sc., biology
- **Joël Boudreault** M.A., philosophy

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APPENDIX 1 HEALTH CANADA'S BTI FACT SHEET

Health Canada | Santé Canada

Your health and safety… our priority. | Votre santé et votre sécurité… notre priorité.

Bti – Bacillus *thuringiensis subspecies israelensis*

Canada

Bacillus thuringiensis subspecies *israelensis*, commonly referred to as Bti, is a bacterium found naturally in soils. Since 1982, it has been used successfully worldwide as a biological pest control agent to combat mosquitoes and black flies.

How does Bti work?

During the spore-forming stage of its life cycle, the Bti bacterium produces a protein crystal which is toxic only to mosquito and black fly larvae. These microscopic crystals are ingested by insect larvae when they are feeding. In the alkaline environment of the susceptible insect's digestive system, the crystals are dissolved and converted into toxic protein molecules that destroy the walls of the insect's stomach. The insect usually stops feeding within hours and dies within days.

Other subspecies of Bt are registered for use in Canada and these too work only on specific species of insects. For instance, Bt subspecies *tenebrionis* (Btt) is effective against Colorado potato beetles and Bt subspecies *kurstaki* (Btk) works only against a group of insects called lepidopterans, which includes destructive tree pests such as gypsy moths, spruce budworms and forest tent caterpillars.

How is Bti used?

Bti is applied directly to the water where mosquito and black fly larvae are found. The bacteria are suspended in the water where the larvae will ingest it. None of the products containing Bti may be applied to treated, finished drinking water for human consumption.

Nearly all products containing Bti are restricted class products used to control black fly and mosquito larvae in aquatic situations where the flow of water is not confined to a small area. Most provinces require that applicators be certified to use restricted class products. In some provinces, Bti use may also require a permit issued by the provincial pesticide regulatory authority.

Commercial class Bti products are also available, but can only be used to control black fly and mosquito larvae in private ponds and farm dugouts where no outflow beyond the property limits exists. Bti is also used to control fungus gnat larvae in greenhouse ornamental plants.

Are there health concerns related to the use of Bti?

Bti poses little threat to human health through either handling products directly or being exposed to them indirectly, e.g. during a provincial or municipal mosquito control program. To activate Bti toxins, alkaline conditions that exist only in certain insects' digestive systems must be present. The acidic stomachs of humans and animals do not activate Bti toxins. There have been no documented cases involving toxicity or endocrine disruption potential to humans or other mammals over the many years of use in Canada and around the world. Studies have shown that even if Bti spores are ingested or inhaled, they are eliminated without any adverse health effects.

Prior to being permitted for sale or use in or import into Canada, all formulations are evaluated according to internationally-accepted scientific protocols for their potential to cause skin or eye irritation or sensitization and acute toxic effects. These tests are

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What is the effect of Bti on the environment?

Bti only becomes toxic in the stomachs of mosquito and black fly larvae. Because of this, it does not affect other insects, honeybees, fish, birds or mammals. The United States Environmental Protection Agency categorizes the risks posed by Bt strains to non-target organisms as *minimal to non-existent*. The insecticidal toxin biodegrades quickly in the environment through exposure to sunlight and microorganisms.

What is the impact on our water supply?

Registered products containing Bti are primarily intended for use by trained applicators in federal, provincial and municipal mosquito and black fly programs. Label restrictions for these products permit the application only to the aquatic sites where mosquito and black fly larvae are found, and not to treated, finished drinking water. Following a review of human health risk assessments, Health Canada has determined that products containing Bti do not pose any health risks to humans and other mammals.

Based on the lack of human health risk and long history of safe use associated with Bti and other varieties of Bt, the PMRA has no human health and safety concerns with the application of registered products containing Bt to bodies of water that will be used for human consumption. The direct application of Bti to treated, finished drinking water, however, is not considered acceptable practice by the PMRA.

How can you be sure that Bti is not affecting health or the environment?

Different varieties of Bt, including Bti, have been widely used in insect control programs in Canada and the US for many years and have demonstrated a remarkable safety record. The weight of scientific evidence indicates that Bti is non-infectious and non-toxic to humans and other mammals and poses little risk at dosage levels permitted in insect control programs. While adverse effects have been observed in individuals of some non-target aquatic insect species, no lasting impact on the populations of these species has been shown from use of Bti.

For more information about pest control products, contact Health Canada's Pest Management Information Service at 1-800-267-6315 or at (613) 736-3799 (outside of Canada).