Everything you should know about *Bti*

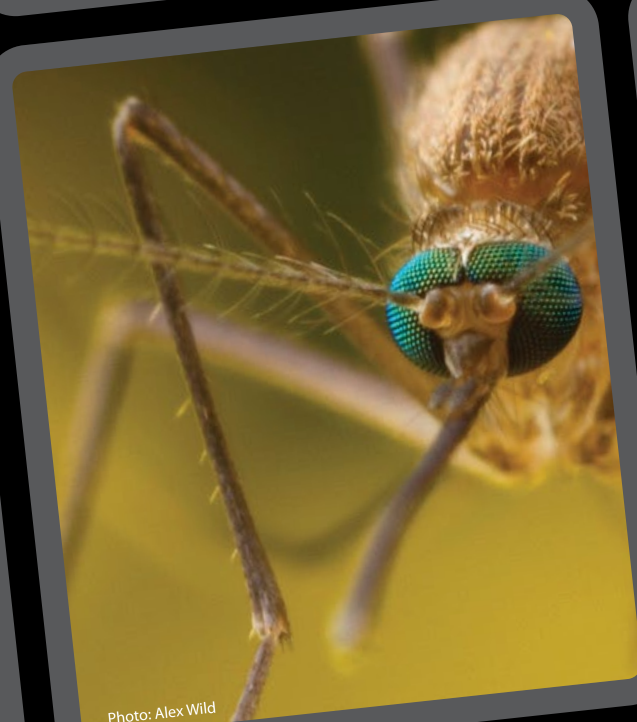
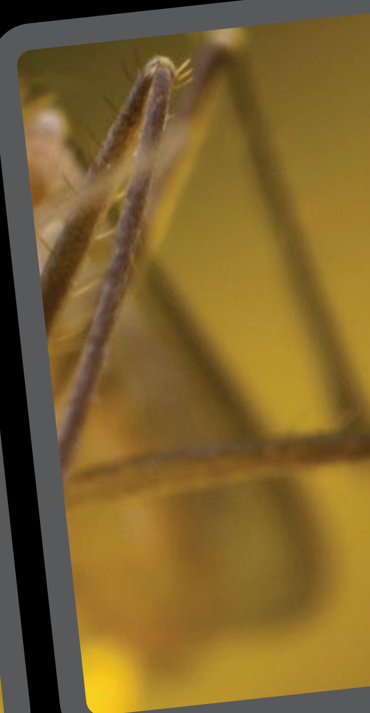


Photo: Alex Wild



Notice to the reader

This document is more a scientific popularization tool, that answers frequently asked questions about Bti, than an extensive literature review. If you wish more information on the subject, please consult the references provided at the end of the document.

Acknowledgments

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Graphic design: *Paul Berryman*

Above those named, *G.D.G. Environnement* would like to thank those part of the team that have participated in the making of this document (*Réjean Bergevin, Stéphanie Moreau, Nathalie Nadeau, Gregory Roy, Richard Vadeboncoeur*) for their outstanding work.

Contents

Everything you should know about ***Bti***

? ANSWERS to your QUESTIONS

Bacillus thuringiensis israelensis is a bacterium found naturally in soils. Other subspecies of Bt are registered for use in Canada and these too work only on specific species of insects.

How is Bti used?

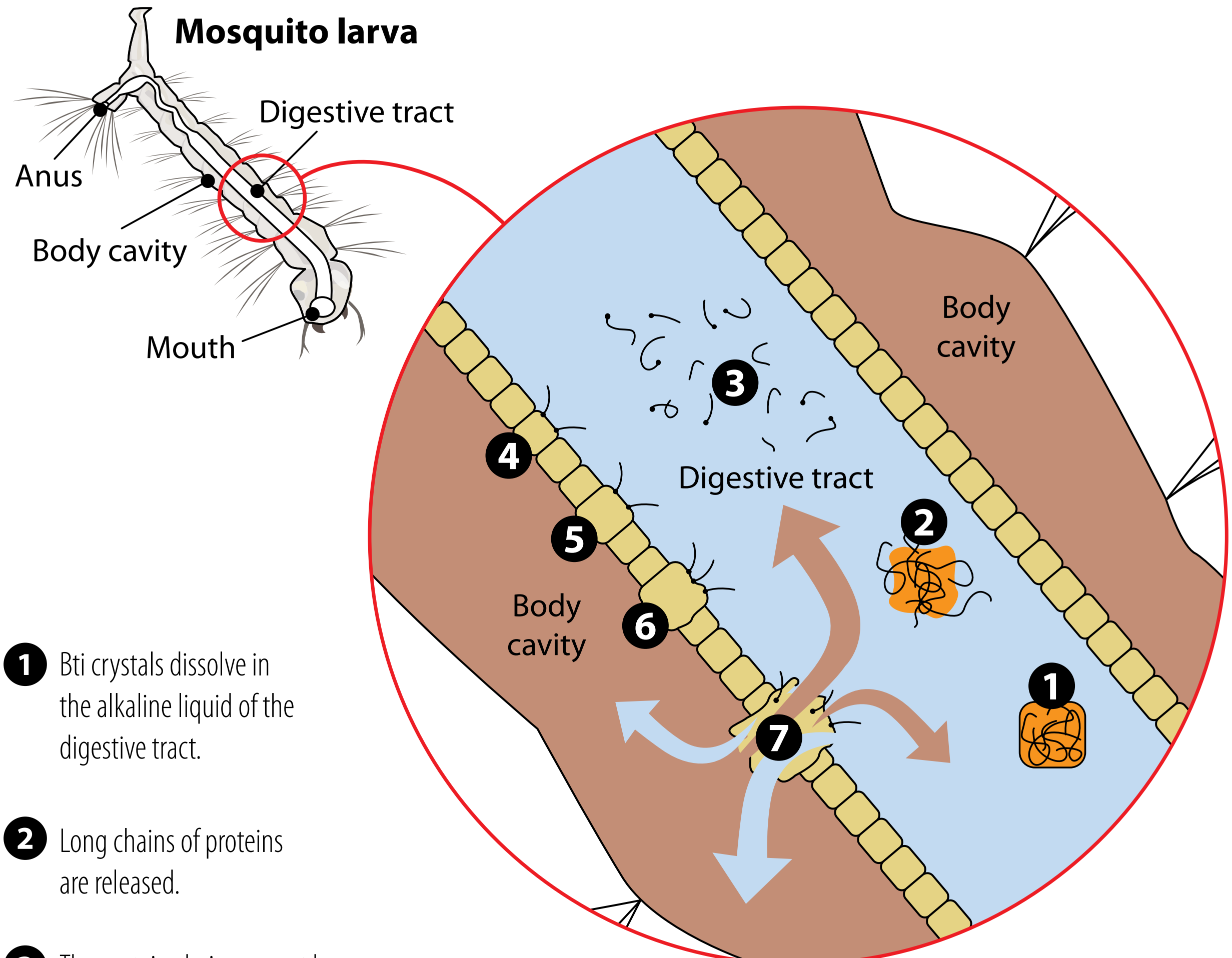
Bti is used to control mosquitoes and black flies. It is also used in the prevention of diseases transmitted by mosquitoes, such as West Nile virus, and allows a better quality of life for people affected by the nuisance caused by these insects. Bti is a non-toxic environmentally friendly solution for humans and animals and is rapidly degraded in the environment. It has no significant impact on the eating habits of other animal species. This bio-larvicide is applied to standing or running water, or where the mosquitoes and black flies lay. The fight against biting insects using biological larvicides, shows a collective sensitivity to the preservation of natural environments and can contribute to achieving a better balance between the actions of nature and those of man.

Since when do we use Bti?

Bti was first isolated from mosquito larvae in an isolated stagnant pond in the Negev Desert of Israel by Goldberg and Margalit during the 1976 summer. Their work was published in 1977 and, since 1982, Bti is used throughout the world for the biological control of 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.



1. Bti crystals dissolve in the alkaline liquid of the digestive tract.
2. Long chains of proteins are released.
3. The protein chains are cut by the enzymes.
4. The segments, which are toxic to the cells of the digestive tract, cling to these cells.
5. Under the effect of the toxin, the cells begin to swell.
6. The cells continue to swell and weaken.
7. Eventually, the affected cells burst causing a perforation of the digestive tract which produces the movement of digestive juices to the body cavity and a reverse motion of the blood of the insect.

The bursting of the digestive tract causes the death of the insect.

Does Bti affect honeybees?

The effects of *Bacillus thuringiensis israelensis* (Bti) on honeybees have been extensively studied (Krieg 1980; Vandenberg and Shimanuki 1986; Vandenberg 1990; Malone 1999). No adverse effects from Bti treatments on plants that bees forage upon have been reported nor are there impacts on bees or honeybee colonies. A 2012 study by Frank Aletru, head of a honeybee research center in the Vendée region of France (Centre vendéen de recherche et sélection apicole), demonstrated that Bti is non-toxic to honeybees and does not affect hive activities (Aletru 2012). The study found no loss of foragers (field bees), no excess mortality in workers, no behaviour abnormalities and no appearance or development of disease in broods or adults. In fact, an experimental hive located in an area that received 10 times the normal amount of Bti turned out to be the best honey producer. In addition, an Ontario Ministry of Agriculture and Food publication classifies Bti as non-toxic to honeybees. Furthermore, Bti is not intended to be applied on plants but in aquatic environments.


Photo: Jerzy Strzelecki

Does Bti accumulate in the soil?

Numerous studies have shown that *Bacillus thuringiensis* (Bt) persists in the soil mainly in the form of spores and that very little multiplication of vegetative cells occurs (Boisvert and Lacoursière 2004). In addition, solar radiation, particularly UV rays, quickly degrades bacterial spores (Kwang-Bo and Côté 2000). Bt is not intended to be applied directly to the soil, moreover, repeated applications of Bt do not result in the accumulation of bacteria in the soil (Dulmage and Aizawa 1982).

Does Bti influence soil productivity and fertility?

According to Lacey 2007, products containing Bt are very unlikely to affect the productivity and fertility of soils, since this bacterium already occurs naturally in the environment. Bt persists for only a short time in the soil and does not accumulate there.

Is there any risk to plant life?

Bt is non-toxic to vegetation since terrestrial and aquatic plants do not have the structures required to ingest the crystals and activate the toxins (USDA 1995). Bti is not intended to be applied on plants but in aquatic environments.

Is there a risk to human health if Bti is deposited on fruit or vegetable crops during activities such as aerial spraying?

Health Canada's *Pest Management Regulatory Agency* (*PMRA*) acknowledges that possible exposure to Bti in agricultural products may occur. It should be noted, however, that Bti is used as an alternative to chemical insecticide to control certain types of flies in the production of mushrooms. The *U.S. Environmental Protection Agency* concludes that this poses no health risk to the general population, including infants and children (PMRA 2006 & Journal of the AMCA 2007).

If a certified organic crop comes into contact with Bti, will it maintain its certification?

Products containing Bt, such as Bti or Btk, are those most commonly used worldwide in organic agriculture, forestry and public health (control of biting insects disease vectors). In United States, selected formulations (ex : *VectoBac WDG*) hold an *OMRI* certification and are *NOP* (*National Organic Program, USDA*) approved. The various formulations of *VectoBac* also benefit from a certification by *Ecocert* in France proving their compatibility with organic agriculture. It should be noted that these products do not contain any GMO. The *Manuel des intrants biologiques: Productions animales, végétales et acéricoles* contains a list of most of the input products approved for use in organic production. It is available online at no charge, in French only, at http://www.cetab.org/system/files/publications/mib_2014.pdf. For government-mandated aerial spraying operations, certification decisions are made on a case-by-case basis by the certifier. However, some other Bt formulations are certified. Bti is not intented to be applied directly on the crops but in aquatic environments. It is recognized that Bti has no effect on fruits or vegetables.

Could Bti contaminate my well and drinking water?

Bti accumulation or dispersion should not occur in the soil with common usage. As previously mentioned, Bti is used in aquatic environments. The spores of this bacterium are definitely not transported in water to other locations in the soil. Consequently, during frequent flooding in spring and fall, spores do not appear to move from treated to untreated areas (Guidi et al. 2011), which confirms the results of previous studies. Furthermore, Bti poses no risk to human health, since human beings do not have the structures required to activate the toxin in Bti. Although drinking water cannot be treated with Bti under Canada's very strict laws on pesticides, the *World Health Organization Pesticide Evaluation Scheme* (*WHOPES*) authorized its direct application in drinking water in a 2009 report, which demonstrates that the product is totally safe for humans. Furthermore, a study published in 2011, conducted in a natural wetland reserve in Switzerland, concluded that, based on the results of 22 years of Bti treatments, Bti is not harmful for the environment and does not contaminate untreated areas (Guidi et al. 2011).

Would a world without mosquitoes have adverse consequences on ecosystems?

A world without mosquitoes would be safer for humanity, according to medical entomologist Carlos Marcondes from the Federal University of Santa Catarina in Brazil, quoted in an article in the July 2010 issue of the journal *Nature* (Fang 2010). Mosquitoes transmit numerous diseases, including West Nile virus, malaria and dengue fever. A world without mosquitoes would benefit not only people but also wildlife, particularly caribou in Canada's Far North (Fang 2010). Every year, the biomass of mosquitoes hatching in the swath across northern Canada and Russia is so great that it is unmatched elsewhere in the world, according to entomologist Daniel Strickman, the Program leader for medical and urban entomology at the *U.S. Department of Agriculture*. The swarm of mosquitoes makes it difficult for caribou to migrate since the mammals must change their path and face into the wind to avoid the biting insects. In such a harsh and inhospitable region, this change in route could have major consequences on a herd's survival. Most programs treat only a small area, so there is no significant impact on ecosystems.

Photo: Wikimedia Commons

Would reducing mosquito populations through the use of Bti treatments affect the survival of bats?

In general, bats are opportunistic, with their diet reflecting the availability of prey items. In the event of a massive emergence of mosquitoes, bats may turn to this food source momentarily.

According to medical entomologist Janet McAllister of the *Centers for Disease Control and Prevention* in Colorado, bats feed mostly on moths, with mosquitoes making up less than 2% of bats' stomach contents (Fang 2010). PCR techniques used in excrement analysis now make it possible to accurately determine which insects are ingested by bats. Recent studies support the hypothesis that bats are affected only slightly by the decrease in mosquito populations. Instead, other factors are harmful to bat populations, including deforestation, urbanization and the use of agricultural pesticides, which can accumulate in the tissues of bats when they eat insects treated with pesticides.

An interesting study published in 2013 shows that it is not to bats' advantage to feed on mosquitoes, since they would need to ingest between 604 and 659 mosquitoes a day to meet their energy needs, compared with only 164 to 179 moths. Feeding on mosquitoes requires a greater foraging effort, which is a disadvantage. In addition, mosquitoes are small prey and some bat species (the largest ones) cannot detect mosquitoes by echolocation, owing to their lower echolocation call frequencies (Gonsalves 2013).

Eight species of bats occur in Eastern Canada, all insectivorous: silver-haired bat, hoary bat, little brown, northern, small-footed, eastern pipistrelle, big brown and eastern red bat.

A 2009 study found that beetles account for 22% of the diet of the little brown myotis, with flies (not including mosquitoes) accounting for 16%; moths, 31%; and other insects, 31% (Moosman 2012). According to another study, the species' diet varies depending on the point in the maternity season: early in the season, gestating females concentrate on flies other than mosquitoes (63% of diet), but at the end of gestation, mayflies play a prominent role (66% of diet) (Clare 2011).


Eastern small-footed myotis • *Wikimedia Commons*

The big brown myotis (*Eptesicus fuscus*) also feeds predominantly on beetles and moths, although its diet may vary depending on environmental conditions (Moosman 2012). A 2012 study revealed that the species' diet consists of 81% beetles, 1% flies, 4% moths and 14% other insects (Moosman 2012). When beetles are scarce, the species turns to caddisflies (small, moth-like aquatic insects) and true bugs (Agosta 2002).

In summer, the diet of the hoary bat (*Lasiurus cinereus*) consists mainly of moths, beetles, dragonflies and true bugs and not mosquitoes (P. Reimer et al. 2010). A study published in 2009 found that, in spring, the species feeds exclusively on moths (Valdez 2009).

The diet of the silver-haired bat (*Lasionycteris noctivagans*) consists mainly of insects of the order Homoptera (P. Reimer et al. 2010).

The eastern pipistrelle feeds primarily on chironomids (non-biting midges) and caddisflies, which make up the vast majority of its diet (Kalko 1995).


Tree Swallow • *Simon Pierre Barrette*

Would reducing mosquito populations through the use of Bti treatments affect the survival of insectivorous birds like swallows?

Cathy Curby, a wildlife biologist at the *U.S. Fish and Wildlife Service* in Fairbanks, Alaska, believes that mosquitoes are not an important food source for insect-eating birds, since they do not show up in bird stomach samples in high numbers (Fang 2010). According to a 2013 study in the *Italian Journal of Zoology*, the diet of the House Martin does not consist of mosquitoes, but rather of *Hymenoptera* such as ants (77.6%), as well as beetles (15.65%) and true bugs (4.99%) (Boukhemza-Zemmouri et al. 2013). In addition, a study published in 2013 in the *Journal of Applied Ecology* found that the long-term use of Bti-based products in French Atlantic coastal wetlands had no effect on the diet of birds, since the amount of invertebrates that could be used as food resources by birds was maintained even in treated areas (Lagadic 2013). This is the most extensive long-term investigation conducted in France to date on the effects of Bti on non-target aquatic organisms. Another study has concluded that Bti poses no risk of indirect negative effects on birds feeding on chironomids (non-biting midges, which resemble mosquitoes) (Lundström et al. 2010). The same conclusion applies to birds, bats and frogs.

Six species of swallows occur in Eastern Canada: tree swallow, purple martin, cliff swallow, barn swallow, rough-winged swallow and bank swallow (AAHQ 2014). According to the *ministère du Développement durable de l'Environnement et la Lutte contre les changements climatiques*, none of these aerial insectivores are considered threatened or vulnerable.

Tree swallows, according to one study, feed on insects from 10 different orders, as well as on spiders and molluscs such as snails. Interestingly, the diet of nestlings consists of dragonflies, as well as insects of the order *Homoptera*, even though *Diptera* (the order that includes mosquitoes) are more abundant in the environment (Mengelkoch et al. 2004). Another study, carried out in 2013, confirms that mosquitoes are not an important prey item for tree swallows, making up less than 1% of stomach contents in the birds analyzed (Beck 2013).

A literature review on Purple Martins concludes that mosquitoes are not a major food source for Purple Martins, as they generally hunt for insects on the wing above the trees and in open spaces, where mosquitoes are not usually found (Kale 1968).

Barn swallows feed primarily on beetles and, according to one study, even when smaller prey are available in the environment, they will chose larger prey to feed the nestlings (Orlowski et al. 2011). Barn swallows are often associated with barns and farms since they feed on the beetles found in manure. They are also probably associated with the type of livestock present (Grzegorz et al. 2013). The disappearance of barns and livestock-raising operations in Quebec poses a greater threat to the species than the use of Bti.

Will reducing populations of biting insects through the use of Bti treatments affect the survival of fish?

Brown trout • *Wikimedia Commons*

Balanced stream and river ecosystems contain food webs in which blackfly larvae are not the sole source of food for aquatic predators. The more diverse the food web, the less the likelihood of significant repercussions from the complete or partial elimination of a single species.

The scientific literature contains numerous studies on the diet of the various fish species found in Quebec and Ontario. For example, a 2004 study on Atlantic salmon and brook trout (MOOKERJI et al.) indicates that mosquitoes play a minor role in the diet of those fish. A 2011 study on brown trout fry found that their most common insect prey items were chironomids (non-biting midges) and mayfly nymphs (Sánchez-Hernández 2011). According to the study, chironomids represented 59% of all the insects identified in the stomach contents of the young fish. Other insects identified included caddisflies, stone-flies, mites and flies, along with copepods (small crustaceans). Although applications of Bti in aquatic habitats kill blackfly and mosquito larvae, the dead larvae may be consumed safely by various species of insectivorous fish.

Does Bti affect chironomid populations?

Chironomidae larvae • *Erin Hayes-Pontius*

A number of studies have demonstrated effects on populations of chironomids (non-biting midges) (Boisvert and Boisvert 2000). However, these studies have involved dosages greater than those specified on product labels and, at the specified dosages for products used to control biting insects, Bti has no effect on chironomid populations. Furthermore, in a six-year-long study on the floodplains of the River Dalälven in Sweden, researchers showed that Bti had no significant effects on chironomid abundance or species richness (Lundström et al. 2010). Another study published in 2013 on the effects of Bti treatments on non-target aquatic organisms echoes the 2010 study, concluding that Bti is not harmful to chironomids at recommended application rate for the control of mosquitoes or biting flies. (Lagadic 2013).

Does Bti directly or indirectly affect amphibian populations?

According to a report by New Zealand's Ministry of Health, no direct effects from Bti have been observed in amphibians (Glare and O'Callaghan 1998). In addition, in an analysis of a number of laboratory and field studies on the potential impacts of Bti on frogs, newts, salamanders and toads, no direct effects were reported (Glare and O'Callaghan 1998).

Since Bti treatments result in decreased quantities of mosquitoes in the environment, some might think that this would have an impact on amphibians' food chains. The results of a number of studies on the subject suggest, on the contrary, that these treatments have no impact, since mosquitoes appear to be a negligible food source for amphibians.

A study on the tetraploid grey treefrog, which occurs in Quebec, shows that its diet consists mainly of ants and beetles, and does not include mosquitoes (Mahan and Johnson 2007).

Studies on the diet of the eastern red-backed salamander and eastern newt show that mosquitoes are a negligible food source for these amphibians (Burton 1976). Red-backed salamanders feed mainly on mites but may also consume other insects such as non-biting midges, crane flies, beetles and moths, while eastern newts eat mainly snails, but may also feed on red mites, spiders and springtails.

All these amphibians are generalized insectivores, in other words, they consume a wide variety of insect prey (Jaeger 1981). Therefore, even if mosquito populations decrease, this will not have an effect on amphibians' survival.

Red-backed Salamander • *Brian Gratwicke*

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G.D.G. Environnement is a unique center of expertise dedicated to finding solutions to environmental issues. Throughout Eastern Canada, the organization conducts biological control of biting insects operations (mosquitoes and black flies) in order to reduce the nuisance caused by these species. *G.D.G. Environnement* also performs actions to prevent the spread of mosquito-borne diseases such as the West Nile virus.

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Notes