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Blackflies (Simuliidae)

Peter H. Adler, in Reference Module in Biomedical Sciences, 2020

Biology and ecology

Blackflies occupy two profoundly different environments—the aquatic and the terrestrial. The dichotomy sets up a paradox whereby the immature stages are ecosystem benefactors but the adults, more specifically the females, are often in direct conflict with humans and their enterprises. Society is, therefore, faced with safeguarding its citizens and economic interests while conserving the ecological benefits of blackflies.

Blackflies are found everywhere that freshwater flows, including desert oases and remote oceanic islands. They are remarkably common insects. In any given area of the world, they are typically found in 90% or more of flowing water habitats, from the tiniest streams to the largest rivers. Although they are generally associated with clean waters, some species are quite pollution-tolerant. Mountainous

areas of the globe, which offer a wide range of habitats along an elevation gradient, typically have the greatest number of species. Blackflies are often the most abundant macroinvertebrates in running water, reaching densities of 1 million larvae per square meter in extreme cases (Wotton, 1988).
The larvae attach to objects in the current, such as stones, trailing vegetation, and refuse (e.g., plastic), by enmeshing tiny abdominal hooks in a silk pad spun from the large silk glands. About 30 highly specialized species are phoretic, attaching to, and developing on, larval mayflies (Ephemeroptera) in Africa and Central Asia and to freshwater crabs and prawns in tropical Africa (Crosskey, 1990). Larval life concludes with spinning a silk cocoon in which molting to the pupa occurs. The compact pupa, with its conspicuous pair of respiratory organs (gills), is adapted for gas exchange in water or in air if decreasing water levels strand it.
The larvae of all but 1% of the world's species are filter feeders, capturing fine particulate matter (0.09–350 μm in diameter) with their labral fans and processing it into fecal pellets rich in carbon, nitrogen, and bacterial films, which become available as food to other aquatic organisms (Malmqvist et al., 2004). Fecal production by larval black flies can reach astonishing levels—429 metric

tons of dry mass passing a river site per day—prompting researchers to refer to black flies as "ecosystem engineers" (Wotton et al., 1998; Malmqvist et al., 2001). Larvae also feed by scraping adherent material from the substrate; the 25 species that lack labral fans do so exclusively. Some species, especially those living in nutrient-poor streams, ingest small prey items. Larvae disperse or relocate by moving inchworm fashion or drifting on silk lifelines that they spin. Peak drifting of larval black flies occurs around dusk.

The egg stage can last a few days to years, depending on environmental conditions such as temperature and water availability. Some species undergo an obligatory egg diapause through the winter or the summer. Larvae can develop in as few as 4 days to as long as 6–9 months, depending largely on temperature. They typically pass through six or seven instars, although more if parasitized or starved. The pupal stage usually lasts a few days to a few weeks. The entire life cycle from egg to adult can be completed in 2 weeks or less, with some species in tropical environments completing as many as 15 or more generations per year. Univoltine species, those that complete a single generation annually, are associated with northern environments and high elevations. Adults emerge from the pupa in a partial covering of air and fly to a nearby location to tan and harden the body and wings.

The essentials of adult life are completed within a typical lifespan of a month or less: mating, sugar feeding, and for the females, blood feeding and egg laying. Mating takes place shortly after emergence, usually when males form swarms into which entering females are intercepted. These swarms typically form over landmarks, such as waterfalls, tips of tree branches, and bare ground. Less frequently, males and females locate one another and mate on the ground near the emergence site. About 15 species are parthenogenetic; males do not exist.

About 97.5% of all species have mouthparts fitted for cutting animal tissue. The other 2.5% of species, all in far-northern or extreme high-elevation environments, have mouthparts incapable of cutting animal tissue; they mature their eggs without blood (obligate autogeny). In cooler environments, larvae with high-quality diets produce females that can mature their eggs without benefit of a blood meal for the first cycle of egg production but require blood for subsequent egg batches (facultative autogeny). Most species of blackflies, however, require blood for all cycles of egg maturation (anautogeny).

Multiple gonotrophic cycles of blood feeding and oviposition are possible and are prerequisites for parasite acquisition and transmission. Females of some species, particularly certain vectors in the *Simulium damnosum* complex, can disperse up to 500 km before a blood meal, although dispersal distances of fewer than 20 km are typical for most species (Crosskey, 1990). The female flies locate their blood hosts—exclusively birds and mammals—by a series of cues, such as host color, size, shape, and odor, especially carbon dioxide (Sutcliffe, 1986), which provides an effective method of sampling and trapping female flies.

Female flies deposit their eggs directly into the water during flight, or they lay them in strings and masses while walking on wetted surfaces or vegetation trailing in the current. Communal egg laying on substrates is mediated in some species by pheromones emitted from the freshly deposited eggs (McCall et al., 1997). The number of eggs matured in one ovarian cycle varies from 30 to more than 800, depending on the species (Crosskey, 1990). Although the blood hosts of most species of blackflies are unknown, the general feeding habits can be inferred from the structure of the claws. Females that feed on mammals have curved claws, with or without a small basal tooth, whereas females that feed on birds have curved talons with a variably sized thumblike lobe that aids purchase as the flies move through feathers. Thus, roughly 51% of all bloodsucking species of blackflies feed predominantly on mammals and the other 49% on birds. At times, however, some species feed indiscriminately on birds and mammals, regardless of claw structure. Mammalophilic blackflies, including anthropophilic species, typically do not venture into enclosures to acquire blood meals. At least some ornithophilic species, however, frequently enter avian nest cavities and other enclosures (e.g., bird houses). Host tissue is cut by the serrated mandibles, which operate as micro-scissors to produce a pool of blood that is imbibed (Sutcliffe and McIver, 1984). Blackflies are determined feeders, typically completing a blood meal on a single host animal, acquiring about 2 µl or more of blood per meal. The numerous molecules in simuliid saliva play a variety of roles: localized anesthesia, prevention of clotting, modulation of the host immune response, inhibition of platelet aggregation, enhanced vasodilation, and direction of microfilarial parasites to the feeding site (Cupp and Cupp, 1997; Stallings et al., 2002).

The various life-history attributes of blackflies, such as requirements for flowing water, egg diapause, aerial swarming for mate finding, and blood feeding, can complicate sustained laboratory colonization.

Few species, consequently, have been colonized for more than one generation. The most prominent exception is the abundant North American species *Simulium vittatum*, which has been in perpetual laboratory colonization for nearly 40 years without introduction of wild material since its inception (Gray and Noblet, 2014).

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http://www.blackfly.org.uk/simbiol2.htm#contents

Larva

The egg hatches to produce a larva which has a distinct, sclerotized head with paired, simple eyes, and an elongated

hour-glass shaped body, in which the thorax and posterior part of the abdomen are broader than the anterior segments of the abdomen. The head bears a pair of cephalic (labral) fans, homologous structures to the lateral palatal brushes of mosquitoes. They do not create a current but filter water passing over the larva. The larva has a single anterior proleg, surmounted by a circlet of hooks and the abdomen ends in a posterior circlet. The anus opens dorsally of the posterior circlet, and from it may be extruded the rectal organ, which probably, by analogy with the anal papillae of culicid larvae, is concerned with chloride extraction from the water. The larva spins a web of silk on the substrate, which is continued into a silken thread on which the larva drifts downstream with the current in search of a suitable object on which to settle. When this has been found, the larva spins a patch of silk to which it anchors itself by its posterior circlet of hooks. Larvae normally remain near the surface of the water and are usually found at depths of less than 300 mm (except for some large river species which may be found at depths of several meters in turbulent water). The larva can change its location by drifting downstream on a silken thread, or by looping over the substrate surface using the posterior circlet and the hooks on the anterior proleg to retain a hold on secreted silk. Some species disperse further from the oviposition site than others.

In normal feeding position the larvae are anchored posteriorly and extended in the direction of the current

with the head downsteam. The body is twisted through 90-180° so that the fans and mouthparts face towards the surface of the water. The water current is divided by the proleg and directed towards the fans. A sticky secretion produced by the cibarial glands enables the fans to capture fine particles, which are transferred to the cibarium by the mandibular brushes. Larvae of some species defend their territory and are aggressive to their upstream neighbours, who would be competing for the incoming food. Territorial defence declines dramatically when food is abundant. Simuliid larvae ingest particles such as bacteria, diatoms and silt up to 350 μm, but the most commonly ingested particles are 10-100 μm. Algae pass apparently unchanged through the blackfly gut but diatoms may form as much as 50% of the gut contents. Filter-feeding larvae of some species may also browse on the substrate while a few do not filter feed at all but only graze on the substrate.

Go to CONTENTS

Simuliid larvae are particularly abundant where the water current accelerates, as at rapids, where presumably larvae will strain a greater volume of water per unit time. Heavy larval concentrations are often to be found at the outflows of large lakes, where the water will be rich in phytoplankton for larval food. Movement of water over the body surface provides the larva with adequate dissolved oxygen for respiration. In deoxygenated water larvae detach and drift downstream.

Simuliid larvae reach a length of 4 to 12 mm, and being reasonably large and aggregated, are easily seen on submerged objects. The larvae of a few species are phoretic on freshwater crabs and mayfly nymphs.
The mature last instar larva, recognised by the presence of a dark "gill spot" through which the developing gills

of the pupa may be seen, on the lateral side of the thorax, is actually a pharate pupa within the larval skin (i.e. midway between loosening the larval skin and casting it off), and may move to a different site before pupating. In most species the pharate pupa spins a cocoon in which it pupates. This is usually slipper-shaped with the closed end directed upstream and the open end downstream (Fig. 6). This alignment prevents the cocoon being torn off the substrate by the current. Construction of the cocoon takes about an hour and then the larval skin is shed.

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Fecal pellets from a dense aggregation of suspension-feeders in a stream: An example of ecosystem engineering

Roger S. Wotton, Björn Malmqvist, Timo Muotka, Kristina Larsson
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https://aslopubs.onlinelibrary.wiley.com/doi/abs/10.4319/lo.1998.43.4.0719

Abstract

Blackfly larvae (Diptera: Simuliidae) are “allogenie ecosystem engineers” that capture fine particulate and dissolved matter from suspension and egest much larger fecal pellets. We investigated the effects of blackfly larvae on organic matter transport at 25 sites along a small stream that flowed 500 m from a lake to the sea. Blackfly density was high upstream (>6 × 10^5 ind. m^{-2}) and the numbers of fecal pellets in suspension rose markedly downstream from the blackfly aggregation. A total of 1.6 × 10^9 fecal pellets (biomass 3.2 kg C d^{-1}) were discharged to the sea each day and 8.0 × 10^8 pellets (biomass 1.6 kg C d^{-1}) were lost from suspension. Sedimenting pellets were available to the benthic microbial and invertebrate communities.

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Intensity and Importance of Abiotic Control and Inferred Competition on Biomass Distribution Patterns of Simuliidae and Hydropsychidae in Southern Québec Streams

Antoine Morin

- Abstract
- PDF

Abstract

Biomass of Simuliidae larvae was measured on individual rocks in four surveys of southern Québec streams to quantify the intensity and importance of relationships between biomass of black flies and microhabitat features (depth, current velocity, rock size), site properties (distance from the lake, seston quality), and biomass of Hydropsychidae. Microhabitat features and site properties accounted for 14-47% of the variability in biomass of hydropsychids and simuliids on individual rocks, and between 30 and 67% of variability in mean biomass across sites. Addition of biomass of potential competitors did not significantly improve the proportion of variability accounted for by the multiple regression models. Within most sampling sites, biomasses of simuliids and of hydropsychids were positively correlated. However, analysis of microdistribution patterns across sites suggests a small but significant negative partial correlation between hydropsychids and simuliids in summer and a positive partial correlation in winter. Analysis of covariance revealed strong site effects that could not be explained by microhabitat features or biomass of potential competitors. These results suggest that hydropsychids have a negative effect on biomass of simuliids in summer, but that biomass of simuliids in different sites is more influenced by microhabitat features and site properties than by the biomass of hydropsychids. Reanalysis of published work on interactions between simuliids and caddisflies suggests that intensity of competition is relatively constant, but that its importance is overestimated by controlled experiments. Quantitative models describing the distribution of filter feeders across sites should include better correlates of site suitability rather than considering abundance of competing groups.

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Download references

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DEP sprays waterways to control black flies

OUTDOORS

MAY 11, 2021

JOHN ZAKTANSKY
Middle Susquehanna Riverkeeper

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Late in the afternoon on April 28, Thomas Grove was fishing along the Susquehanna River just downstream from the mouth of the Penns Creek when a red helicopter flew straight toward him from Hoovers Island.

"They hovered just above the shore line at Hoovers and dumped some kind of reddish-brown liquid into the river," he said. *"They flew across the river directly upstream from us directly in the Penns Creek discharge toward Route 15 dumping the remaining fluid into the river."*

Grove reached out to the Middle Susquehanna Riverkeeper Association with some photos and one very important question: *“What were they dumping into the river?”*
The response, according to DEP aquatic biology supervisor and statewide Black Fly Suppression Program manager Douglas Orr: *“Bacillus thuringiensis israelensis”* more commonly referred to as BTI.
“BTI is a soil bacteria-based product — a pesticide derived from natural materials so it is called a bio pesticide,” he said. *“It is not a chemical, it is not a contact killer. Also, it photodegrades quickly, so it doesn’t build up in the environment.”*

BTI is used specifically to control populations of black flies along 1,700 miles of 48 rivers and streams in 35 Pennsylvania counties.
“Black flies have basic guts, where we all have acidic guts, and this material requires an alkaline-type environment to work,” he said. *“Once it is in the black fly’s gut, it breaks down the lining of the stomach and kills them from the inside out. It doesn’t hurt humans or fish or other nontarget insects, this compound is specific to black flies and mosquitoes.”*
BTI was first registered by the U.S. EPA as an insecticide in 1983 and is used widely because of its species-specific properties, safety to non-target organisms, rapid breakdown and reduced insect resilience, according to a fact sheet about the compound

found on the DEP's Black Fly Suppression Program website.

"It has even been approved for use in organic farming operations — it is a very safe product," said Orr, who added that dispersal of BTI is managed very closely.

"BTI looks like chocolate milk — as if you are taking a gallon jug of chocolate milk and dumping it. Helicopters have an open boom on the side, and biologists on the ground have calculated specifically how many gallons should go into each site using USGS flow gauges and other calculations," he said. *"We talk with pilots before they take off, we hand them the map of the region to be targeted. It is all computerized in the cockpit, they punch it in, fly out across the stream and that material comes out of the side of the helicopter (in specific doses)."*

One of the most common misconceptions involving the program revolves around the definition of a black fly.

"People don't fully understand what a black fly is. They assume that any fly that is black is a black fly, and that isn't true," said Orr. *"Black flies are the small gnats that swarm around your face and head. While they don't bite everybody, they can still have a ferocious bite. They are not houseflies or manure flies or other larger flies that you may see around. We have been called to manure fly or housefly outbreaks, and it is hard to tell people that we are the black fly program, and we don't target their specific fly issue."*

Black flies need fast-flowing, clean water to survive.

“Adult black flies lay their eggs in riffle areas of streams and rivers. They are also filter feeders, taking organic matter out of the water, and need fast-moving water to get enough water to filter,” said Orr. *“Adult flies can fly 20 to 30 miles away from their original stream once they hatch, so our goal is to locate and properly spray these riffles before they come out as adults and they expand too quickly to properly manage.”*

On certain smaller streams with expanded tree canopy, helicopter spraying is replaced by individual application via backpack sprayers, which helps them treat more remote regions on a regular basis to stay ahead of the rapid reproduction cycle of the black fly.

“These species can produce anywhere from 10 to 12 generations per summer. We try to spray each time we have a mature larval group in the river, and can spray as much as needed until funding is exhausted,” said Orr. *“When water temperatures rise in the summer, the frequency definitely increases.”*

Black fly research in the state was sparked decades ago when a nationally recognized golf tournament was impacted by swarms of gnats.

“There was a Women’s Open in Hershey, and they had trouble with gnats interrupting the tournament,” said Orr. *“Around the same time, a group called Neighbors Against Gnats — or NAG — campaigned for research to be done on how to better control black fly populations.”*

The resurgence in black flies was directly connected to legislation passed in the state around that time, Orr added.

"They started coming on strong and re-entering our streams when the clean water act was instituted which started cleaning up our waterways and since black flies need clean water to survive, they became one of the few unfortunate negative effects of having lean water," he said. *"Each time we clean up a river, black flies repopulate. The Upper Conemaugh is an example. It was recently cleaned up, and now we are spraying because of an increase in black fly populations."*

Funding for this program, according to DEP community relations coordinator Meghan Lehman, is multi-faceted.

"Funding comes from a line item in the state budget, but a portion comes from the counties who choose to participate," she said. *"If commissioners agree to get involved, they kick in funding toward spraying. It isn't in all counties – only those who have chosen to participate."*

In ideal conditions, Orr relays that BTI is nearly 100 percent effective if applied properly.

"Overall, we hope to have around 85 to 90 percent control, which is a great rate considering this is a bio pesticide and not a chemical," he said. *"We have said that we will never use chemicals on Pennsylvania waters, and this solution works amazingly well."*

The Black Fly Suppression Program is an example of one of the wide array of services by the DEP in which many people don't realize unless it isn't working, added Lehman.

"Being out camping, hiking and recreating, this program has a concrete aspect on people's lives, but it also has an economic benefit," she said. *"For example, the Little League World Series Complex sits next to the river, and there is always an effort beforehand so that black flies don't wreak havoc at the Little League World Series. That is no way to welcome people from all over the world – the last thing we'd want to see on national television are people swatting at flies during games."*

As one who spends lots of time on the river, Grove appreciated the update on his submitted email and photos, something he felt compelled to share because he loves the river and the aquatic ecosystem it supports.

"We all baby this river. Many of us are quick to release the bass we catch and we are cautiously observant any time something is added to the environment because the balance can be really fragile," he said. *"You look at all the industrial and other negative impacts we've had over the years, and yet these bass keep finding a way to adapt and thrive."*

For more information about the DEP Black Fly Suppression Program, visit www.dep.pa.gov/Business/Water/CleanWater/BlackFly/Pages/default.aspx

https://www.sungazette.com/news/outdoors/2021/05/dep-sprays-waterways-to-control-black-flies/

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https://www.sciencedirect.com/topics/earth-and-planetary-sciences/particulate-organic-matter

Impacts of Hydrological Alterations on Water Quality

Meenakshi Arora, ... Michael J. Stewardson, in Water for the Environment, 2017

6.5.2 Anthropogenic Influences

Elevated dissolved or particulate organic matter loading often reduces oxygen concentrations by supporting heterotrophic microbial activity and hence oxygen consumption. The additional organic matter may be contributed by allochthonous sources including blackwater draining of floodplains, where dissolved organic matter is leached from leaf litter and sewage spills (Hladyz et al., 2011; McCarthy et al., 2014), or from autochthonous processes stimulated by eutrophication such as algal blooms (Mallin et al., 2006). Consequences of low dissolved oxygen concentrations, or hypoxia, in streams include: altered fish behavior (Dwyer et al., 2014); increased mortality of fish (Small et al., 2014) and freshwater crustaceans (McCarthy et al., 2014); and reduced richness and abundance of zooplankton (Ning et al., 2015).

Reaeration is highly dependent on flow-mediated mixing across the air–water interface. Reduced flow velocities, and hence turbulence, will reduce reaeration rates and can lead to declining dissolved oxygen concentrations within the water column. These conditions are likely in ponded water (e.g., upstream of weirs), particularly if this occurs in combination with reduced flows.

Density stratification of water bodies can occur as a result of either surface water heating (thermal stratification) or inputs of salt from seawater, groundwater, or other sources (salinity stratification; Williams, 2006). A vertical temperature or salinity gradient (thermocline or halocline) produces density differences, with the more buoyant (higher temperature or lower salinity) water *floating* at the surface above the denser (colder or higher salinity) water. Under these conditions, reaeration of the bottom layer requires the downward exchange of dissolved oxygen across the interface between these two layers. Alternatively, reaeration can occur by mixing of the water column and elimination of the stratified conditions. Both these processes are flow-dependent. Increases in flow generally enhance exchange of dissolved oxygen and mixing of the two layers by producing greater shear and hence turbulence at the interface. As with the oxygen exchange at the air–water interface, reduced flows in regulated rivers or impoundment of rivers by weirs will increase the risk of establishing stratified conditions and reduce gas exchange to the lower layer, resulting in hypoxic conditions lower in the water column.

Reservoirs are particularly prone to the formation of temperature stratification as surface waters are heated during the warmer season. The colder hypolimnion often becomes anoxic. If reservoir releases draw water from the hypolimnion, then the downstream river will experience low dissolved oxygen. However, this effect will be attenuated rapidly downstream, with high reaeration rates produced by a large gradient in oxygen concentrations at the water surface.

Anthropogenic influences on morphology of river channels often reduce channel irregularities including removal of meanders and bedforms (Hancock, 2002). These features are critical to hyporheic exchange and their removal changes the distribution of hydraulic controls in river systems, generally reducing the supply of dissolved oxygen to streambed sediments (Hanrahan, 2008). In addition, elevated suspended sediment loads in response to catchment disturbances may clog bed sediments and also inhibit dissolved oxygen exchange across the sediment–water interface.

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Vulnerability of Water Resources to Climate

A.I. Shiklomanov, R.B. Lammers, in Climate Vulnerability, 2013

5.11.1 Introduction

The Arctic is undergoing marked changes in response to climate. Numerous studies indicate that the global climate signal in the Arctic is pronounced and has already exceeded natural climate variability (ACIA 2005). All components of the arctic ecosystem are intimately linked to all others and water plays a central and unique role in this system. There is mounting evidence that the region is experiencing an unprecedented degree of environmental change in various components of the water cycle. These include loss of permafrost (Yang et al. 2002); change in river flow volume (Lammers et al. 2001; Peterson et al. 2002; Shiklomanov and Lammers 2009) and timing (Shiklomanov et al. 2007; Tan et al. 2011); lengthened ice-free periods in lakes and rivers (Magnuson et al. 2000; Vuglinsky 2002); disappearance of lakes (Smith et al. 2005); reductions in snow cover (Armstrong and Brodzik 2001); and melting of glaciers (Steffen et al. 2004). Streamflow changes are strongly related to climate variability, disturbance in land cover, degradation of the cryosphere, and direct human impact. River flow is an integrated characteristic reflecting numerous environmental processes and their changes aggregated over different size areas. River runoff also plays a significant role in the freshwater budget of the Arctic Ocean (Serreze et al. 2006). Ocean salinity and sea ice formation are critically affected by river input. Changes in the freshwater flux to the Arctic Ocean can exert significant control over global ocean circulation by affecting North Atlantic deep water formation (Manabe and Stouffer 1994; Rahmstorf 2002). Arctic drainage basin river flow is thus likely to serve an important role in regulating the heat balance of the planet (Peterson et al. 2006). The freshwater cycle of the Arctic therefore takes on a central role in our understanding of the influence of global change on terrestrial ecosystems and on the connection of the northern land mass to the Arctic Ocean (Lammers et al. 2001).

5.11.1.1 Definition of Domain

Our understanding of the Arctic Ocean's freshwater budget variability requires analysis of hydrological processes across the entire river runoff formation zone covering both the Arctic Ocean watershed and the adjacent territories from which the runoff contributes to the ocean freshwater budget. The entire Pan-Arctic hydrological domain covers a region of approximately 24 million km^2 (including Greenland) and represents a significant part of the global land surface in the north. The region is characterized and defined hydrologically by the north flowing rivers entering the Arctic Ocean, Hudson Bay, James Bay, the Canadian Arctic Archipelago, the far north Atlantic Ocean, and Bering Strait including much of Alaska (Shiklomanov et al. 2000; Lammers et al. 2001; Forman et al. 2000) (Figure 1). Although the Hudson Bay, James Bay, and Bering Strait are located outside of the Arctic Ocean drainage basin, the rivers draining into these water bodies supply a large amount of freshwater discharge to the Arctic Ocean via the north-flowing oceanic currents (AMAP 1998). Thus, it is important to take into account the river discharge from these drainage basins when assessing the dynamics of the river flux into the Arctic Ocean. The headwaters of the large Arctic rivers such as Nelson, Ob, and Yenisey drainage basins extend halfway to the equator to a latitude of 45°N. Thus, a significant part of the Pan-Arctic hydrological domain is located in temperate climate zones and is covered not only by tundra, but also by boreal–taiga forest and grassland.

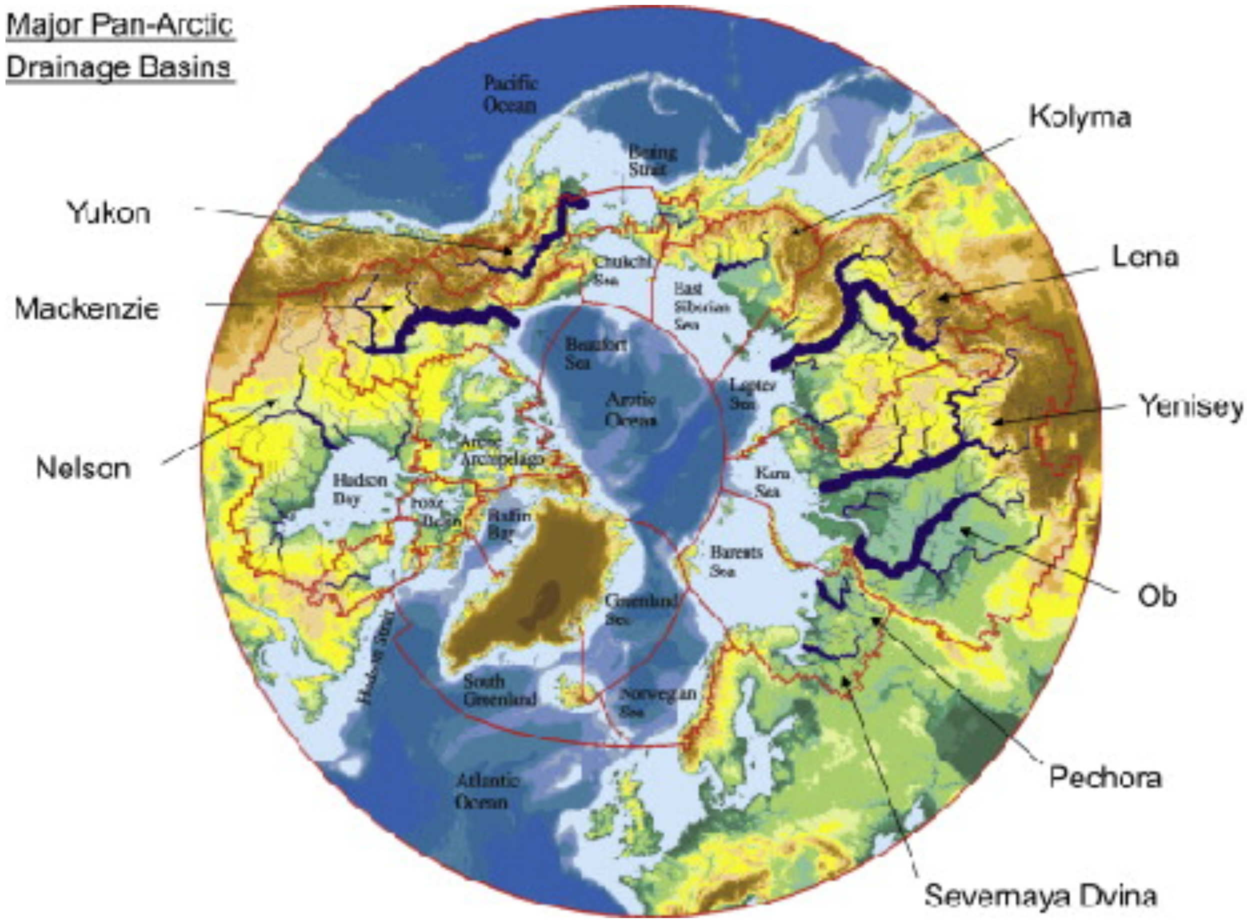

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Figure 1. Major northern rivers (dark blue lines) and seas (red outlines) of North America and Eurasia. Background coloring shows elevation and bathymetry relative to sea level.
Forman, S. L., W. Maslowski, J. T. Andrews, D. R. Lubinski, M. Steele, J. Zhang, R. Lammers, and B. Peterson, 2000: Researchers explore arctic freshwater's role in ocean circulation. *EOS Trans. Am. Geophys. Union*, **81**, 169–174.

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CHROMOSOMAL PATTERNS IN POPULATIONS OF THE BLACK FLY SIMULIUM FIBRINFLATUM TWINN (DIPTERA: SIMULIIDAE)
A Thesis Presented to
the Graduate School of Clemson University
In Partial Fulfillment
of the Requirements for the Degree Master of Science Entomology
by Kyle Parks August 2012
Accepted by:
Dr. Peter Adler, Committee Chair Dr. John Morse
Dr. John McCreadie

Despite notoriety as pests, black flies have important ecological functions where they are abundant. Black fly larvae are major contributors to carbon retention in streams and rivers where they play a crucial role in converting floating organic particles into fecal pellets that are dense enough to sink (Wotton et al. 1998). Rather than flowing away, those organic particles then accumulate on the bed and banks of the stream and can fertilize vegetation (Malmqvist et al. 2001, Wotton et al. 1998). The black flies themselves are also important food items. Both larvae and adults are preyed on by birds, fish, and numerous invertebrates. Around 70 species of fish are known predators of black fly larvae (Davies 1981). Plecoptera, Trichoptera, Odonata, and Diptera larvae prey on black fly larvae (Malmqvist et al. 2004), and at least one adult black fly has been found in the larval cell of one species of sphecid wasp (Krombein 1960). Furthermore, the
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adults of many black fly species are nectar-feeders and contribute to the pollination of flowering plants (Malmqvist et al. 2004).

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Malmqvist B, Wotton RS, Zhang Y (2001) Suspension feeders transform massive amounts of seston in large northern rivers. Oikos 92:35–43

Suspension feeders transform massive amounts of seston in large northern rivers

Björn Malmqvist, Roger S. Wotton, Yixin Zhang
First published: 15 April 2003 **https://doi.org/10.1034/j.1600-0706.2001.920105.x**
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Abstract

The concentration and transport of faecal pellets (FPs) produced by blackfly (Diptera: Simuliidae) larvae were estimated in a large, free-flowing river in the north of Sweden during 1997–1999. FPs were abundant from May through August and FP loads in transport peaked at 429 t dry mass d−1 at a site in the lower part of the river in 1997. Daily transport at the same site, averaged over each study period (16 Jun.–18 Sep. 1997, 6 Apr.–10 Sep. 1998, and 21 Apr.–5 Aug. 1999), was estimated to be 93.7 t dry mass (3.7 t carbon), 47.5 t dry mass (1.9 t carbon and) and 69.2 t dry mass (2.7 t carbon), respectively. On a large scale, there was a downstream trend of increasing FP concentration and, during periods with greater discharge, sedimentation was reduced so that more material was exported from the river. Samples from six sites in a regulated river (into which our focal river flows) parallel to six sites in the unregulated tributary showed considerably lower FP concentrations in the regulated river, presumably because of much smaller blackfly populations as a consequence of habitat loss through damming. A survey of two other large, unregulated rivers in northern Sweden confirmed that these also carry large amounts of FPs. We conclude that the transformation of small suspended food particles into considerably larger FPs by huge populations of filter-feeding blackfly larvae is a major process in large northern rivers.

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Experimental Applications of B.t.i. for Larval Black Fly Control: Persistence and Downstream Carry, Efficacy, Impact on Non-target Invertebrates and Fish Feeding

by

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Experimental Applicatons of B.t.i. for Larval Black Fly Control: Persistence and Downstream Carry, Efficacy, Impact on Non-target Invertebrates and Fish Feeding

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TABLE OF CONTENTS

INTRODUCTION

Biting and s\\ arming black flies can cause serious discomfort to humans in Maine. In spite of this problem, the advisability and means of reducing their numbers remain controversial. Control is generally aimed at the larvae in streams. Environmentalists are concerned with the persistence of control materials in streams used as drinking water and for recreation, and that control agents aimed at black fly larvae will affect non-target forms in the stream. Historically, these concerns have made serious consideration of black fly control measures in Maine unacceptable.

The most promising control agent available at present is the biological insecticide Bacillus thuringiensis var. israe/iensis de

Barjac (B.t.i.). This material and its use in the field have been reviewed (3, 4 and 6). It is a spore forming bacterium which, at sporulation, produces crystals of toxic protein which are lethal to larvae of mosquitoes and black flies when ingested. B.t.i. does not normally cause infectious disease which spreads from insect to insect through transmission of spores. The insecticidal crystalline toxin acts as a stomach poison and has no contact effect. The crystal is a protoxin which is broken down in the midgut of susceptible larvae into toxic sub-components. This conversion seems to occur only in mosquitoes, black flies and some related Diptera and so to account for the host specificity of the material. Laboratory and field studies have shown that a wide range of non-target organisms occurring with black flies and mosquitoes are not susceptible to B.t.i. or are susceptible only at dosages greatly in excess of those used in control opera- tions. Only Diptera closely related to black flies such as some Chironomidae and Blepharoceridae (1,3 and 4) have been shown to be susceptible. Increased drift in Ephemeroptera and Trichoptera was shown in one study (5), but other reports showed no effect on these insects.

Various factors may influence the insecticidal activity against black fly lar- vae. Laboratorv studies have demonstrated the effects of temperature, larval age, species of black fly, concentration of inoculum and formulation on insecticidal activitv (4). Additional factors, such as stream discharge and profile (especially depth-to-width ratio), turbidity, turbulence, density of aquatic vegetation and filter feeding organisms, dilution of B.t.i. and duration of treatment may influence larvicidal activity under field conditions.

In the summer of 1985 a field experiment was conducted in the Sugarloaf area of Maine on the use of B.t.i. to reduce the numbers of black fly larvae in the Carrabassett River and a tributary stream. The objectives were to determine the rate of application necessary to produce an acceptable reduction in black fly larvae, to study the fate and persistence of B.t.i. in a stream following application, to determine the impact of B.t.i. on the abundance and drift of non-target stream insects and on the feeding success and diet composition of fishes in the treated streams.

STUDY AREA

The study area was the Carrabassett River in the area of the golf course at Sugarloaf, Maine and a tributary here designated as No Name Stream which flows east under Rte. 27 at Bigelow before joining the Carrabassett. The application site on the Carrabassett River was near the upstream boundary of the golf course just above the upper bridge. The stretch of the river above the application site is referred to as the control area and that below as the treated area. Sampling stations were established at intervals downstream from the application site. The same procedure was followed on No Name Stream.

The black fly fauna of the study area was surveyed in 1984 (K. E. Gibbs and K. R. Hardy, unpublished report to the Sugarloaf Mountain Corpora- tion). Black fly larvae were abundant in the Carrabasset River and No Name Stream, and the species causing the greatest human nuisance by biting and swarming were Prosimulium fontanum Sy me and Davies, P. mixtum Sy me and Davies, Simulium venustum Say, S. corbis Twinn, S. parnassum Malloch, S. tuberosum (Lundstr.) and Stegoptema mutata (Malloch).

METHODS AND MATERIALS

B.t.t. and Application Procedures

The formulation of B.t.t. used was the aqueous suspension, Yectobac®
(AS)-14 manufactured by Abbott Laboratories. Four experimental appli- cations were made during the summer as shown in Table 1.

Application was by direct metered introduction into the stream and fol- lowed the method of D. P. Molloy, New York Museum and Science Service, New York State Education Department, Albany, New York, 12230 (personal communication).

Fate and Persistence ofB. t. i.

It should be noted that, though spores/ml of water may not be directly and consistently related to toxicity, their use in discussing movement of treat- ment suspensions is valid. The intent of this study was to examine the distribution of B.t.i. spores as a reference to the distribution of the spore crystals. This experimental application was made on August 5 when the discharge of the river was 0.15m^3/sec. Rhodamine-B dye was used to determine the time taken for transportation of material from the application site to the sampling stations. B.t.t. was applied at the rate of 10 ppm for 5 min, 2 min after the dye was applied. The concentration of spores passing through sampling stations at 150 m, 750 m and 1250 m was monitored starting at 2 min after the dye reached each station. Water samples were taken at 3 min intervals for 30 min and then at 5 min intervals for the next 30 min.

Concentrations of B.t.i. spores in water at the sampling sites were deter- mined following the method of Frommer (2). Pre- and post-treatment water samples were collected in 1.25 ml containers by submerging the containers midstream at a medium water depth for each time-distance. Water samples were kept refrigerated until processed in the laboratory. On the day plate counts w ere prepared, a 10 ml aliquot of each sample was removed from the water bottle after the bottle was shaken vigorously bv hand. Each 10 ml aliquot was heat shocked in a water bath for 30 min at 6()°C (prior to preparation of the dilutions to be plated). Samples were heat shocked to eliminate background vegetative stage bacterial

and fungal contaminants. Sterile distilled water blanks were used to prepare serial dilutions of the samples. Initiallv, tenfold dilutionsw ere used but later fivefold dilutions were used. Dilutions were prepared using Corning plastic disposable pipettes, then thoroughly mixed with a Vortex mixer. One ml of each dilution to be plated was added to a 10(1 x 15 ml petri dish and slowly swirled to spread the
B
spores. Approximately 1 5 ml of molten Difco
added to each plate. Agar was maintained liquid throughout the procedure. Solidified agar plates were incubated for 15-17 h at room temperature.

The number of colonies resulting was counted using a Fisher colonv counter. The dilutions selected to determine the concentration (i.e., the number of colonv forming units per ml) were represented bv the plates containing between 30 and 300 colonv forming units. Three plate replications were prepared for estimating mean spores/ml for each time and distance.

Impact on Invertebrates

The impact of B.t.i. applications on black fly larvae attached to the subs-
trate and in the drift, and on non-target invertebrates in the substrate and in the drift, was measured.

Percent Mortality ofBlack Fly Larvae. Percent mortality of black fly larvae was calculated bv counting the numbers of living and dead larvae on natural rock substrates at downstream treated and upstream control sampling stations following B. t. i. application. Attempts to use artificial substrates in the form of plastic streamers were abandoned as the streamers were only lightly and irregularly colonized. Counts were made 2-6 h, and on one occasion 24 h, after application. Living and dead larvae were identified to species.

Drift. Duplicate 15 min drift samples were taken in the control area and in the treated area 225 m below the application site in the

Carrabassett River dur- ing the June 17 and July 1 1 treatments. Similar procedures were followed for the July 11 application in No Name Stream except that the nets in the treated area were 50 m below the treatment site. The nets used were 16 cm high, 34 cm wide and 1 m long, with a mesh aperture of 350 jjm. All material in the
tryptose blood agar base was

drift was immediately preserved in 95% ethyl alcohol. The volume of water
passing through the net during the sampling period was determined by
2 measuring the flow rate (m/s) and the area of the net submerged (m). The
numbers of organisms drifting were calculated in numbers per unit volume
3
of water (n/m) in order to reduce the variability caused by variable flow.
The final numbers presented represent means of the duplicate samples or, in a few cases where one was lost, onlv one sample.
Substrate Samples. To determine if applications of B.t.i. caused changes in the standing stock (numbers) of non-target macroinvertebrates (mainly aquatic insects) in the stream bottom, artificial substrates were placed in the stream bottom three weeks before the sampling date to allow time for colonization. The substrates consisted of "rock bags' or plastic mesh bags (grocery store fruit bags) filled with 2 kg of rocks having a maximum diameter of 5-6 cm. Five of these bags were removed from the control and treated areas of the stream pre- and post-treatment with reference to the June 17 and the July 11 applications to the Carrabassett Riser and No Name Stream, respectively. The organisms were washed from the rocks and those retained by a

#40 sieve were preserved in 8()'\, ethyl alcohol and returned to the laboratory for sorting and identification.

Impact on Fish Feeding

Only brook trout (Sa/ve/inusfiintinalis (Mitchill)) and slimy sculpins (Cot-
tus cognatus Richardson) were common in reaches of the Carrabassett River and No Name Stream included in the study. Thus, onlv these two species were collected for analysis.

Fish Sampling and Gut Content Analysis. Fish were sampled from control and treated areas, pre- and posttreatment, from the Carrabassett River with reference to the June 17 application and from No Name Stream with reference to the July 1 1 application. Fish were collected bv electro-shock- ing, and an attempt was made to obtain 10 fish of each species from each area on each date. All fish were immediately preserved in 80% ethyl alcohol, and the larger fish were slit along the abdomen to allow penetration of the preservative. In the laboratory, weight and total length of the fish were determined and the fish stomach and intestine were removed. The volume of the gut contents was determined by volumetric displacement in the barrel of either a 1 or 3 ml syringe. The gut content was then placed on a grid under 10.x magnification and separated into the following cate- gories: Simuliidae (black fly) larvae, Blepharoceridae larvae, other Diptera (mainly Chironomidae) larvae, Diptera pupae, Ephemeroptera (mayfly) nymphs, Plecoptera (stonefly) nymphs, Trichoptera (caddisfly) larvae, terrestrials (insects and spiders which had fallen into or onto the water

from the terrestrial environment), miscellaneous (unidentified material including organic and inorganic material such as leaves and sand ingested incidentlv u ith the food material). Black fly larvae are distinctive because of the well sclerotized head capsule and cephalic fans and could be easily identified. The number of black fly larvae in each gut was recorded as was the number of fish in the sample containing black fly larvae. The percent of the total gut content represented by black fly larvae was determined by counting the number of squares of the grid covered by black fly larvae divided by the total number of squares covered by all the material present. The number of fish in which thev occurred and the percent of total gut content were determined for the other food categories.

RESUL TS

Fate and Persistence o/B.t.i.

Pretreatment background spore counts were at insignificant levels in
stream water and thus did not interfere with the analysis of samples collected post-treatment. The dve reached 150 m in S min, 750 m in 41 min and 1250 m in 1 h and 33 min. Water sampling was initiated 2 min later. The distribution of spores as thev moved through the down stream collecting stations is shown in Fig. 1. Results at the three sites differ in time to peak concentration, peak concentration attained, concentration spread in relation to the 5 min application time and rates of ascent and descent of spore concentrations following the initiation and termination of application. At the 150 m site the time to peak concentration was 6 min, at 750 m 15 min, and at 1250 m 15 min (the only time at which a spore count over the minimum level of detection was recorded). At 150 m the peak concentration was 10,025 spores/ml, at 750 m 2,340 spores/ml and at 1250 m 780 spores/ml. Spore counts above 30 spores/ ml were obtained for 18 min at 150 m, for 29 min at 750 m but onlv at one time at 1250 m. The time to maximun count at 150 m was 9 min, at 750 m IS min, and at 1250, 15 min.

Impact on Black I'ly Larcae

Mortality of black flv larvae achieved in the three treatments in the Carra- bassett River is shown in Tables 2, 3, 4 and in No Name Stream in Table 5. In the June treatment in theCarrabassett River of 10 ppm for 1 min, a maximum mortality of 6S% was attained 300 m below the application site (Table 2). In the July treatment at 10 ppm for 5 min, however, 98 - 100'\> mortality was attained up to 450 m below the application site (Table 3). Results from the August application at the same rate showed a similar trend with a 100"o mor- tality at 150 m and 85.6% mortality at 750 m (Table 4). In No Name Stream

93.5 - 100% mortality was achieved atl0ppmfor5 minupto 150 m below the application site (Table 5).

In the Carrabassett River, both the June 17 and July 1 1 applications of B.t.i. resulted in an immediate and substantial (8 and 20X respectively) increase in drift of black fly larvae (Fig. 2 and 3). Drift increased within 2 h of the B.t.i. application and had returned to pretreatment levels by the follow- ing morning. The most prevalent species in both June and July were S. tub- erosum, S. cori/s and S. venustum (Fig. 4 and 5). Larvae in the drift in the treated area immediately following treatment were dead and many showed signs of tissue breakdown. Black fly larvae were rare in the drift in No Name Stream both before and after the B. t.1. application. No data are presented for this stream.

Impact on non-target invertebrates

There was no evidence of a decrease in numbers of any of the taxa encoun- tered in the substrates which could be attributed to the B.t.i. applications (Tables 6, 7, and 8). Increases or decreases in numbers in the treated areas which are paralleled by increases or decreases in the control areas must be attributed to factors such as recruitment or adult emergence rather than the B.t.i. application.

Taxa other than black fly larvae frequently encountered in the drift were Ephemeroptera, Chironomidae, Blepharoceridae and Acarina. There was no evidence of increased drift of any of these organisms following B.t.i. applications in the Carrabassett (Fig. 2

and 3). Organisms were rare in the drift in No Name Stream both before and after the B.t.i. application. No data are presented for this stream.

Impact on Fish Feeding

Analysis of the gut contents of slimy sculpins in No Name Stream and the Carrabassett River is shown in Tables 9 and 10. In No Name Stream (Table 9), out of 32 fish examined, only one black fly larva was found. Of a total of 39 fish collected in the Carrabassett River (Table 10), only five contained black fly larvae, and these contained only one black fly larva each. The mean percent of the total diet represented by black fly larvae ranged from 0-1.7%. Sculpins appeared to rely heavily on aquatic insects other than black fly larvae. In the Carrabassett River, mayflies, and in No Name Stream, chiro- nomid larvae, were especially important.

Analyses of gut content of brook trout in No Name Stream and the Carra- bassett River are shown in Tables 11, 12, and 13. In No Name Stream (Table 11) four of the 33 fish sampled contained one black fly larva each. There were two size classes of brook trout in the Carrabassett River: fry about 3 cm long and adult fish about 7 cm and longer. These two groups were examined sepa- rately. In the fry, (Table 12) six out of 12 fish contained black fly larvae, and

(1

the mean number per fish on sampling dates ranged from (1-3.3. Feeding on black fly larvae in the control area appeared to be heavier than in the treated area. In the larger fish, (Table 13) 1 1 out of 2S fish contained black fly larvae, and the mean number per sample ranged from 0-1.1. There was a slight increase in numbers of black fly larvae ingested between pre- and posttreat- ment dates in both the control and treated areas, and it was not possible to attribute any change to the B.t.i. treatment. Trout in both the Carrabassett and Xo Name Stream fed extensively on terrestrial insects that had fallen into or onto the water. These terrestrial insects were abundant in the drift samples.

Data on the length and weight of fishes collected in the Carrabassett River and No Name Stream are included in Appendices ii and iii. Brook trout fry were abundant in the Carrabassett River but not in No Name Stream. The brook trout in both the Carrabassett River and No Name Stream were relatively small fish.

DISCUSSION

In the Carrabassett River, B.t.i. proceeded down stream in the form of an initiallv high concentration, short duration slug which became progressivelv lower in concentration and longer in duration as the slug progressed down stream. Presumablv spores were sedimented to the substrate, adsorbed to larger particles in the water column (large amounts of particulate organic matter were present in the drift), or caught in eddies. In any case, spores had almost disappeared from the water column 1250 m downstream from the application site.

S. tuberosum, S. cordis and S. venustum were the dominant species of black flies present in the Carrabassett River in June and July in 1985. Ninety percent mortality of black fly larvae is considered a satisfactory level of control (D. P. Molloy, personal communication). This level of control was not attained at any distance below the application site at the rate of 10 ppm for 1 min in the Carrabassett River. B.t.i. at the rate of 10 ppm for 5 min produced a satisfactory level of control for approximately 500 m below the application site in the Carrabassett River. Maximum mortality was attained within 2-4 h and did not increase at 24 h. Control in No Name Stream at the same application rate was less efficient, with satisfactory control extending onlv 150 m below the application site. This can be accounted for by the lower discharge in No Name Stream and the presence of pools; portions of the stream where flow is negligible and where the B. 1.1. may drop out of the water column.

Rapid action of the B.t.i. is shown by the immediate and substantial increased drift of black flv larvae following application and by high mortality

of larvae on the substrate within as little as 2 h. Large numbers of black fly larvae drifting were not considered in the living and dead counts. Thus the percent mortality in the treated areas of the Carrabassett River was probably higher than was recorded. There was no evidence of impact on non-target organisms in either the substrate or in increased drift. Increased drift had previously been reported for Trichoptera and Kphemeroptera (5) at an application rate which was the same as the maximum used in this study. The application rate in the studv which reported the increased rate of drift in
1
Blepharoceridae (1) was much higher 5.28 g(LS)" than that used in this
studv.

Slimy sculpins rarely fed on black fly larvae in either No Name Stream or
the Carrabassett River either before or after B. t.i. treatment. Similarly, adult brook trout rarelv fed on black fly larvae in either stream before or after B.t.i. treatment. However, up to 25% of the diet of small brook trout fry in the Carrabassett River was comprised of black fly larvae. Although these data do not indicate a change in numbers of black fly larvae ingested due to the B. t.i. treatment in this experiment this group of fish appears to be more dependent on these larvae than do other fish in the study area. Anv further evaluations of non-target effects of B.t.i. applications should focus on these small fish.

LITERATURE CITED

1. Back, C , J. Boisvert, J. O. EaCoursiere and G. Charpentier. 1985. High- dosage treatment of a Quebec stream with Bacillus thuringiensis serovar, israelensis: efficacy against black fly larvae (Diptera: Simu/iidae) and impact on non-target insects. Can. Entomol. 117:1523-1534.

2. Frommer. R. L., S. C. Hembree, J. H. Nelson, M. P. Remington and P. H. Gibbs. 1981. The distribution of Bacillus thuringiensis var. israelensis in flowing water with no extensive aquatic vegetative growth. Mosquito News 41:331-338.

3. Gaugler, R. and J. R. Finnev. 1982. A Review of Bacillus thuringiensis var. israelensis serotype 14 as a biological control agent of black flies (Simuliidae): 1-17. /// D. Molloy (Fd.), Biological control of black flies (Diptera: Simuliidae) with Bacillus thuringiensis (Serotype 14): A review with recommendations for laboratory and field protocol. Misc. Publ. Entomol. Soc. Am. 12(4):l-3().

4. Eacey, I., and A. H. Undeen. 1986. Microbial control of black flies and mosquitoes. Ann. Rev. Entomol. 31:265-296.

5. Pistrang, I,. A. and J. F. Burger. 1984. Effect of Bacillus thuringiensis var. israelensis on a genetically-defined population of black flies (Diptera: Simuliidae) and associated insects in a montane New Hampshire stream. Can. Entomol. 116:975-981.

6. Undeen, A. H. and L. A. Lacey. 1982. Field procedures for the evaluation of Bacillus thuringiensis var. israe/ensis(Serotype 14) against black flies (Simuliidae) and non target organisms in streams: 25-30). In D. Molloy (Eld.), Biological control of black flies (Diptera: Simuliidae) with Bacillus thuringiensis (Serotype 14): A review with recommendations for laboratory- and field protocol. Misc. Fubl. Entomol. Soc. Am. 12(4): 1-30.

Fig. 1. The distribution of spores at 150 m, 750 m and 1250 m below the B.t.i. treatment site.

Fig. 2. Simuliidae and Chironomidae (Diptera) drifting in treated and control areas of the Carrabassett River following the June 17 treatment with B.t.i.

Fig. 3. Simuliidae, Blepharoceridae and Chironomidae (Diptera) drifting in treated and control areas of the Carrabassett River following the July 1 1 treatment with B.t.i

Fig. 4. Percent composition of species of black flv larvae drifting in the control (C) and treated (T) areas of the Carrabassett River before and after the June 17 application of B.t.i. t. = Simulium tuberosum, c. = Simulium cordis, v. = Simulium venustum, u. = unknown.

Fig. 5. Percent composition of species of black fly larvae drifting in the control (C) and treated (T) areas of the Carrabassett River before and after the July 1 1application of B.t.i. t. = Simulium tuberosum, c = Simulium corbis, v. — S/muhuiu veuustum, u = unknown.

Fig. 6. Acarina and Heptageniidae, Baetidae and Ephemerellidae (Ephem- eroptera) drifting in treated and control areas of the Carrabassett River following the June 17 treatment with B.t.i.

Fig. 7. Heptageniidae, Baetidae and Ephemerellidae (Ephemeroptera) drifting in treated and control areas of the Carrabassett River following the July 11 application of B.t.i.

Table 1. Experimental applications of VectobacK to the Carrabassett River and No Name Stream during 1985.

Date
(1/17 7 1 1 7, 11 S 5
Stream
Carrabassett R. Carrabassett R. No Name St. Carrabassett R.
Applic ation
Rate Duration
(ppni) (min)
111 1 III 5 HI 5 10 5
Discharge
(m-Vs)
II.l5d 11.205 II.(127 0.154
Water
Te mperaturc (°C)
<U 12.1 9.6
-

Table 2. Mortality of black fly larvae in the Carrabassett River following K
treatment with Vectobac (AS)-14 at 10 ppm for 1 min on June 17, 1985. D= dead; A= alive

5. tu•berosum emistum S. corbis Tota 1 " • ; ,
Site DADADADAMortalitv
1
11 7d II 95 0 511m 11 II 1 II 27 34 59 35 52.7
Control (I 12 0 Treated
1511m 44 II II 5oum 51 7 II 4illm 211 17 II Millm 5 29 II "511m II 13 II

II 6 35 51 35 (>().() II 5 211 59 27 68
1 4') 21 67 23
1 0 17 23 47 31
II II 21 0 ^ II
50m*54 2 0 (1 -v 93 106 95 52.7 "after 24 h
Table 3. Mortality of black fly larvae in the Carrabassett River following R
treatment with Vectobac (AS)-14 at 10 ppm for 5 min on July 11, 1985. D=dead; A —alive
S.tuberosum S.Yifiustum s.corbis Tota1 " • ; ,
Site DADADADAMortality
0 II (1 0 -)->! 0
07015(1198.7
->">-) 0 50m141i"J
Control 0 Treated
150m549 T 12 50(1m 19 II 1) 450m107 1 K Millm 55 57 1 750in 41 T1
1 99.(i (1 100
II 58 (1 599
II II 0 19 1)^(1179
(1 3 44 57 111T47
(1 (1 II 11 15 45
90(1m 11 n II
1050m II 25 II 1 (1 II 0 24 (1
99.4 81 41.3
24 00

Table 4. Mortality of black fly larvae in the Carrabassett River following
K
treatment with Vectobac (AS)-H at 10 ppm for 5 min on August 5, 1985.
D=dead; A = alive

S. tuberosum S. venustum s.corbis Total % Site
DADADADAMurtalitv
150m S3 0 10 0 5 0 98 0 100 750m143 24 (1 0 l) 0 143 24 85.6
1250 m 65 117 1) 0 ll II 117 35.1
Table 5. Mortality of black fly larvae in the Carrabassett River following R
treatment with Vectobac (AS)-14 at 10 ppm for 5 min on July 11, 1985 D=dead; A=alive
S. tu berosum S. v viustum 5. corbis Total % Site D A D A D A D A Mortality
Control 0 Treated
6 (1 59
0 411 II
1 67 II
II .i
i
II IS III II 14 II \'l
II 211
ll 0 0 65 0
II II 58 II 100
2 II 89 1 98.8 II u29 3 93.5
019 II 100
ll II2(14 S3
II II 211 33 3/./ ll II 0 25 II
ll II II 28 ll
16
20
14m
50m
100 m
150 m
200 m
250m
i00m II 6 350m II S

29 ll
16 II
i
4 6 33

Table 6. Mean numbers of macroinvertebrates in samples from control and treated areas of the Carrabassett River before and after the June 17 treatment with B.t.i.

Control
Pretreat Post-treat 6/14 6/IK
m 23.4 4 20. N i 3.Q
0.3 1.6
6 2.5
Diptera
Blepharoceridae
Athericidae 0.7
Treated
Pretreat Post-treat 6/14 6/18
15.3 49.2 7.1 25.0 1.7 7.3
1.3 2.5
0.3 2.3
0 0.5
0.3 l.S 12 59.7
3.3 9."! 110.3 4.3 46.7 12.5
1.3 '.() 0.3 2.0
Date
Taxa
Ephemeroptera Ephemerellidae Heptageniidae Siphlonuridae
Plecoptera Perlodidae
Trichoptera Lepidostomidae
Chironomidae Simuliidae
S. venustum S. corbis
S. tuberosum

Coleoptera Elmidae
Acarina
24
0.3 (.2.3 "s ~S
'
0.3
25.5
4.X 3.5 5.0
3..S 1.5
1.3 0.4 1.3

Table 7. Mean numbers of macroinvertebrates in samples from control and treated areas of the Carrabassett River before and after the July 11 treatment with H.t.i.

Date
Taxa
Kphemeroptera Kphemerellidae Kphemeridae Heptagemidae Siphlonuridae
Plecoptera Period idae
Trichoptera l.epidostomidae
Diptera Athericidae Chironomidae Simuliidae
S. venustum S. corbis
S. tuberosum
Coleoptera Klmidae
Acarina
Conti • <>l Treated
Pretreat Post-treat Pretrc;it Post-treat
7/10 7/15 7/10 7/15
0.8 2.8 7 7.8
II 3.5 (1 2.4 19 2141 10.5 20.4 2o 13.(1 20.5 3.0
i(>.5 15.5 17.3 8.8
1.3 3.3 1.5 1.0
4 4 3.3 3 5oo.7 289.5 1S7.25 108.25

2.25 2.S 2.5 3.0 (1 0 II II 3.8 >3 8.8
>.3 9.3 (1.3 3.6 7.5 1.8 2.5 1.2

Table 8. Mean numbers of macroinvertebrates in samples from control and treated areas of the No Name Stream before and after the July 11 treatment with B.t.i.
Pretreat Date 7/11
Ta\a
Post-treat Pretreat Post-treat 7/15 7/11 7/15
Ephemeroptera
Ephemerellidae 0.3 1.5
Heptageniidae 1.0 Siphlonuridae 4.3
Plecoptera
Perlodidae 37.7
Trichoptera
Lepidostomidae 3.3
Diptera
Athericidae 7.7
1
1 0 0 1.7 1.5
23.5 27 1 5
6 0.3 1
3.5 6.0 2.5
Chironomidae Simuliidae
5. venustum S. corbis
S. tuberosum
Coleoptera Elmidae
Acarina
306.5 237.0
0.3 0 1) 1) 0 II
1 0.5 3.3 3.5
305.0 153.0
0.3 0.5 (1 II 1) II

3.3 U 5.3 1.5
Cont rol
Treat ed

Table 9. Diet of slimy sculpins Cottits commitus in No Name Stream before and after treatment with 10 ppm of B.t.i. for (5 minonjulv 11, 1 1S5. P / T = number of fish in which a food category is present/total number of fish in the sample: xn = mean number of organisms per fish; x"u = mean percent of food category in the gut content; Sim. = Simuliidae larvae; Bleph. = Blepharoceridae larvae; C). Diptera = other Diptera larvae; Diptera F. = Diptera pupae; Kphem.= Ephemeroptera nvmphs; Plec. = Flecoptera nvmphs; Tric. = Trichoptera larvae; Terr. = terrestrial invertebrates; Misc. = miscellaneous unidentified material.

Sim. Bleph. O. I)i ptcrd itera P. Date P/T \n \ " i P/T x"„ P/T \"<i I'/T
Fph em. PI ec. Trie. Terr. Misc. 1VT \"u P/T \"n P/T \"„ P/T \ " I \'V
Pretreatment
Control 7/y 11/1(1 (1 II 11/1(1 (1 7/1(1 14.1 II II :/III 0.0 2/1(1 vl
5/1U ".(' 1 '1(1 11.7 dd.3
T r e a t e d 7/9 n/<; [1 Post-treatment
Control 7/15 l/Ki II.1 T r e a t e d 7 / 1 5 W 11
II
11.7 I I
11/')
0/1(1 1 1 / i
(1
(1 (1
Vl>
5/HI 2 / 3
7.3
2.')
1 2 . 1 1
1/'>

11/1(1 1 / ;
(1.4
11 7 . 1
i)/')
2/1(1 1 1 / 5
II
5.4 I I
1 / "
1 i)/)
1 1 / '
II..1
II I I
(I/1)
5/'» 2 / 3
(1
2/) 1 2 . (1
1/4 1.4
l/g 11.7 h / 3 11
74.0
"4.0 5 7 . 5

Table 10. Diet ot slimy sculpi us (Cu/fiu i-of>i/,i//\) in the C';u I ;ih;isstt 1 River before and after treatment with 10 ppm (of H t.i. tor 1 min on)une 17, I'<N5. Conventions as in Table >.

Sim Ulcph. (). D ptel ;i Dipt era P. I'.pl Kill. Plee. 'Iru. 1err. Misc. \ " ' < i

Treated <>/ls (I'Kl II 1) 2 1.9 l/lll 0.4 0 11 1(1/1(1 5S.I 1/10 1.7 1/10 3.1 II II 54.7

Post-treatment

Control 0'20 1/9 11.2 .0 5/9 2.5 0/9 0.0 2/') 11.4 7/9 11.7 2/9 3.2 4/9 5.0 II II 71.7 Treated 0/19 ;, lII 11.5 1.7 2/10 2.1 5/1(1 5.0 II 11 0/111 17.0 0 0 3/1(1 4.9 1/1(1 .IIS 09.0

D a t e P T >v 1 1 \'\ P ' T x " „ P ' T \'\ P / T \ ' ' n P / T \ " d P / T x ' \ , P / T \"., P / T
Control 0/15 l/lt) 0.1 (1.1 5/10 5.1 4/10 1.7 1/10 1.(1 o/IO 2o.s II II 5/1(1 l.« I 1.3 ol.o
Pretreatnient
Table 11. Diet ofadult brook trout [Salvelinus fontinalis) in NoName Stream before andafter treatment with 10 ppm i ofB.t.i. for5minonJulv 11,I'W.VConventions asinTable).
Sim. Bleph. O. D iptera I),, >tera P. Eph em.
Date I'/T \n \ " n P/T x"„ P/T P/T P/T \"<i
Pretreatmcnt
Control 7/9 2/9 11.2 11.5 11/') (1 5/9 2.5 5/9 5.() 4/9 •> - Treated 7/9 2/') 11.2 II. 1 11/9 II 5/9 1.9 1/9 (1.2 2/9 2.4
Post-treatment
Control 7/15 11/III II II 11/1(1 ii 5/1(1 11.9 1/1(1 II.ti 5/1(1 II.S
Treated 7/15(1/5 II II H/5 II 5/5 4.5 5/5 0.7 2/5 9.5
P lee. Trie. Terr. Misc. P'T \".i P/T x'\> P'T \"„ \"<
4/9 2.S r./9 12.U S/9 Io.4 00.5 2/9 II.() 5/9 5.2 S/9 27.S 05.7
11/1(1 (1 I'III 1.9 10/11110.9 S4.S H/5 I) 5/5 0.7 4/5 12.5 05.1

Table 12. Diet of brook trout fry (Sa/vc/inus fontinalis) in the Carrabassett River before and after treatment with HI ppm of B.t.i. for 1 min on June 17, 1^85. Conventions as in table 9.
Sim. Bleph. O 1)l[itera .itera P. Kfihem. P lee. Trie. Terr. Misc.
Date I'T \n \"< IVT P/T IVT IVT \"» P/T \ " n P/T \"n P/T x"«i \ " o
Pretrcatment
Control d/15 2/5 1.3 25.3 II II 5/5 11.5 0/5 II 5/3 21.'I (1 II 1) II 2/5 15.1 27.4 Treated <>/1 5 0/3 II (I II II 5/5 III.S 11/ i II 2/i 5.3 1 1.4 1 1.4 1/3 5.S 71.S
Post-treatment
Control 0/10 2/3 3.3 7.5 l.(, 2/3 (1 11.3 5/i 5.S 11/3 II 3 7.5 3/5 10.2 (.5.5 Treated 0/14 2/3 l.i 5.(1 (1 II 2/5 is.: II II 1/5 12.1 1/5 (..1 1/3 1 3/5 11.1 45.2

Table 13. Diet of adult brook trout (Salve/inns fontinalis) in the Carrabassett River before and after treatment with L
10 ppm with B.t.i. for 1 min on June 17, 1985. Conventions as in Table).
Sim. Bl eph. O. I) iplera Di Pt era P. E ph em. P lee.
Dale P/T \n \"n P/T P/T P/T P/T \": P/T \"n
Trie. P/T v'V
3/7 0.0 4/7 2.1
5/7 4.5 4/7 3.4
1err. Misc. P/T \"n \".
0/7 25.S (.1.1 7 / 7 2 0 . 5 (>2.S
0/7 lll.O 54.S 0/7 21.5 57.4
Prc(rea(mcn(
Control (./I5 0 II II 1/7 0.7 Treated (./1 5 2/7 0.7 0.2 2/7 II.S
Pos(-treatment
Control (./!'(4/7 I.I 2.5 3/7 1.4 Treated 6/10 5/7 I.ll I.ll 3/7 (1.0
II 11 2/7 3/7 0.7 3/7
3/7 3.7 (I 6/7 ?.5 3/7
0.3 2/7 1.2 1/7 II.S 0.4 4/7 d.5 5/7 2.1
11 7/7 20.S 2/7 1.2 1.0 0/7 10.5 2/7 0.5

Location Treated
Control
Species
Brook trout (fry)
Brook trout (juvenile)
Slum sculpin
Number Date of Ki-.li
Weight (g) \ Range
.25 .25 .4 .4

Appendix i. Length and weight of fishes collected in the Carrabassett River.

1 ength (cm)
\ Range
3 3 ()/19 ^ 3.3 3.5
6/15 3
6/15 (i/19
(>/l5
6/15 7 6/19 7
6/13 Il) 6/19 10
(1/19 b/13
7 9.7 " s.l
Id 6.0 1(1 5.9
7.0-13.5 d.S-9.5
3.3-7.9 4.5-7.8
11.4 6.7
2.8 2.6
U-24.4 4.5-8.5
(..7-5.5 1.1-5.6
3 ^
(fry) ()/19,3.53.5 A.4
Brook trout
3
1 1.2 8.4-19.0 9.9 7.7-14.2
d.4 3.8-8.1 5.S 4.2-7.7
.25
19.3 5.9-17.5 1 1.4 4.5-29.6
V .1 0.5-5.2 2.6 1 0-5.6
Brook trout (juvenile)
Slum sculpin
Appendix ii. Length and weight of fishes collected in No Name Stream.
Location Treated
Control
Species Brook trout
Slimv sculpin

Brook trout
Slimv sculpin
Number
Date of Fish \
7/9 11) 6.7 7/15 5 4.0
7/9 9 4.5 7/15 3 3.9
7/9 9 8.3 7/15 III 9.0
7/9 10 5.2 7/15 III 5.0
.ength (cm) Range
\\ eight (g) X ^ange
7.1 5-18.7 4 .88
4.0-11.8
3.2-6.5 5.9
4.4-14.3 4.0-17.8
3.5-6.5 3.3-7.0
1.5 4-2.9 .8 8
7.8 1-33.9 15.2 75-68.2
1.5 4-2.17 1.8 5-4.1
.25

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BIOLOGICAL CONTROL PROGRAMMES IN CANADA, 1981-2000 (CABI)
https://epdf.pub/biological-control-programmes-in-canada-1981-2000-cabi.html

When

11

synthetic pyrethroid resistance occurred, development of biological controls was again emphasized (Watkinson, 1994). Control of Simuliidae now relies exclusively on treating rivers and streams with B.t.i., now the larvicide of choice.