Reprinted from Toronto Entomologists' Association, Ontario Insects, December 2021

Controlling the DD Moth – The good, the bad, and the ugly

Clement Kent, PhD (clementfkent@gmail.com)
Adjunct Prof, Dept. of Biology, York University

Many trees in High Park and elsewhere in Ontario have suffered badly from the latest outbreak of the DD moth (see explanation of the common name below): *Lymantria dispar dispar* (Linnaeus 1758), formerly known as gypsy moth. Although trees usually survive the first year of infestation, multiple years of DD infestation weakens trees severely and may kill them.

Figure 1. *L. dispar ♀ left (by 'Opuntia', GNU License 1.2), ♂ right, Didier Descouens - CB BY SA 4.0*

So, there's lots of pressure from the public to 'control' the DD moth. But before looking at good, bad, and ugly methods, let's look some more at the moth itself, at its evolution, ecology, and behaviour.
Linnaeus himself named this Eurasian species. *Lymantria* means 'destroyer', which is certainly apt, while *dispar* comes from the same root as 'disparate', referring to the visible differences between males and females. Since there is not yet a formal new common name, I'm going to use DD or 'disparate destroyer' here.

In the 263 years since its naming, the genus Lymantria has blessedly remained constant while taxonomists have changed the family and superfamily numerous times. The latest molecular/DNA data says: superfamily: Noctuoidea; family: Erebidae; subfamily: Lymantriinae – tussock moths; and tribe: Lymantriini.

Knowing the evolutionary relationships of DD helps when we look at control strategies. Moth fans know the Erebidae for having the largest moths (the Black Witch moth *Ascalapha odorata* Linnaeus 1758) to many tiny species in the Micronoctuini. Erebidae may have the largest number of moth species of any family. The subfamily Arctiinae includes the often-lovely tiger or woolly bear moths whose caterpillars are so noticeable. The Erebinae is one of the renamed subfamilies that used to be called the Catocalinae, after the underwing (*Catocala*) moths we enjoy.

In many Lymantriinae, caterpillars are covered in irritating hairs which are an important defense against some predators. This is one of the things people dislike greatly when their car or deck gets coated with DD caterpillars. Also, a rash can result from skin contact. Many species also have the adult 'disparity' between males and females, with females often being flightless in the European subspecies *L. dispar dispar* but flying in the Asian *L. dispar asiatica* and Japanese *L. dispar japonica*. Eastern North America females are from the European subspecies, so they emerge, mate, and lay eggs on the tree where they pupated.

So how does DD blanket entire forests with munching caterpillars? This is where the "gypsy" in the earlier species name came from. In spring first instar caterpillars hatch, climb up the tree, and dangle from a silk thread which acts as a parachute when the wind blows. Often this only gets them to the next tree, but the strong storms of springtime can send them many kilometers away. Silk ballooning, as it is called, has evolved in spiders, spider mites, and moths. Another human dispersal method works to our detriment: moving wood with egg sacs allows long jumps.

There are many stories to be told of DD moths, one of the worst of which is its introduction to North America. Étienne Léopold Trouvelot was a French artist and astronomer who emigrated to Medford, Massachusetts after ending up on the wrong side of a political coup. Trouvelot was also an amateur entomologist. Because some native silk-spinning caterpillars were susceptible to disease, Trouvelot imported DD in 1868 to breed a more resistant hybrid species. It escaped his control and became an invasive pest. Although entomologists and foresters might wish his name to live on in infamy, Trouvelot's illustrations of astronomical phenomena were highly valued and he was invited to join the Harvard Astronomical Observatory and the American Academy of Arts and Sciences. Craters on the moon and Mars are named for him.

By 1889 major outbreaks were defoliating forests in New England. DD is now a major pest, causing around a billion dollars of damage each year. But DD is roughly cyclical – a large area may have an outbreak for up to 10 years, but any one location within will only have peak densities for 1 or 2 years. Why?

Natural enemies of DD moth are many, but since it is not native to our continent it doesn't have as many here as in its Eurasian home. Deer mice are thought to be one of the most important predators (of pupae, moths, and egg clusters) when densities are low. Here the ecology gets interesting: deer mice are more abundant in years following an oak "mast" event when there are many acorns to eat. So a big acorn year is followed by a big deer mouse year which helps keep DD numbers down. But a big mouse year increases predators like foxes, and oaks don't mast 2 years in a row so mouse populations can cycle down rapidly the 2nd year. This can relieve mouse pressure on the moths. Other ground-based predators include shrews, voles, chipmunks, and caterpillar-hunter beetles. *Calasoma sycophanta* (Linnaeus, 1758) was imported to New England in 1905 to hunt DD.

Figure 2. *Calasoma sycophanta preys on a DD caterpillar - by Hectonichus CC BY-SA 3.0*

Winter songbirds probe the bark of trees for DD eggs, including chickadees and nuthatches. Spring birds that eat DD caterpillars include blue jays, catbirds, chipping sparrows, crows, cuckoos, grackles, orioles, red-winged blackbirds, robins, starlings, bluebirds, towhees, and vireos. Ornithologist Eugene Morton tells me he had an outbreak at his country property this year and that the cuckoos fed very well. Eugene also saw purple martins carrying as many as 5 male adult moths at a time in their beak to feed to nestlings.

The Australian entomologists and ecologists H.G. Andrewartha and L.C. Birch used long series of data on outbreaks of pest insects such as thrips and grasshoppers to establish how large a role factors like weather could play in insect 'cycles'. Their classic books "The Distribution and Abundance of Animals" (1954) and "The Ecological Web" (1984) are well worth borrowing from a library. Their data and arguments suggest the interaction of 'non-biotic' factors such as weather and biological controls such as natural enemies is important. For the DD moth, 5 days at -25C kills the embryos, so the northern limits of their range will depend on how consistently cold winter is – making Hudson Bay fairly safe but all of Southern Ontario now vulnerable. And spring storm intensities govern spread, while hot dry summers increase larval survival. Climate change will likely increase DD outbreaks in Ontario in each of the 3 seasons above.

The Ugly. As entomologists, we know that some of the most important natural enemies of insects are other insects, especially the parasitoids: wasps, flies, and others. Around 1900, studies in Eurasia of DD showed that the tachinid fly *Compsilura coccinnata* (Meigen, 1824) attacked and killed DD moth caterpillars. Unfortunately, the studies missed the fact that *C. coccinnata* has 3 generations a year while DD has only one. It typically only parasitizes 5% of DD caterpillars in an outbreak, but then goes on to attack some of our most beautiful silkworm moth species and has greatly reduced their numbers. It has been found attacking over 150 moth and butterfly caterpillars. In 1952, Henri Raizenne of the Division of Forest Biology in Ottawa published "*Forest Lepidoptera of Southern Ontario and their Parasites Received and Reared at the Ottawa Forest Insect Survey Laboratory from 1937 to 1948*". Raizenne found *C. coccinnata* in larvae of the Question Mark, Comma, Mourning Cloak, Io moth, Hickory Tiger moth, Sycamore Tussock moth, and probably many others (I only scanned the first 25 pages of this 280 page monograph.)

Given the catastrophic effects of this ugly biological control introduction on so many of our Lepidoptera, one must be careful when we look at other proposed biological controls. We should be especially vigilant about spread from the target DD species to others in the Erebidae.

The Bad. If parasitoids are better than predators as biocontrol, then the fastest reproducing, most efficient natural enemies should be the disease organisms. *Bacillus thuringiensis* (Shigetane, 1902) is a natural enemy of a large number of insect species. It's a bacterium which multiplies in insect guts after the spores are eaten by the larva. It reduces gut efficiency, and when it multiplies it forms long-lasting spores and a set of toxins. These toxins disrupt the larva's gut, often causing death.

There are multiple strains of *B. thuringiensis* in nature. Some are more toxic to lepidopterans, others to flies or Hymenopterans or beetles or nematodes. *B. thuringiensis kurstaki* (BTK) is the strain most toxic to lepidoptera. They have been used for 'organic' control of pests since the 1920s. A 100ml container of Safer's biological insecticide will cost you $12.99 at Canadian Tire. A quart of Monterey B.t. is $53.99 on Amazon and contains "Bacillus thuringiensis subspecies kurstaki strain SA-12 solids, spores and Lepidopteran active toxins (At least 6 million viable spores per mg) ... 98.35%".

One of the best reads on DD and BTK is by Simon Fraser University professor Mark Winston, winner of the 2015 Governor General's award. In his 1997 *Nature Wars: People vs. Pests* he recalls a summer job in the early 1970's: "wandering through through defoliated forests, smelling the stench of rotting gypsy moth larvae that had died from starvation and viral diseases after consuming every leaf in an outbreak area."
Chapter 2 in *Nature Wars* describes the tumult in Vancouver in 1992 after DD moths arrived from the east of Canada on the side of someone's wooden canoe and in large numbers from Siberia on the sides of Russian freighters, leading to the spraying of BTK on 45,550 acres of Vancouver.

A side note: to Hemiptera and Homoptera fans - BTK only affects insects that ingest it from the leaf surface. Sucking insects have been shown to increase in densities after BTK application. Shall we celebrate the replacement of DD rash with aphid honeydew rain?

A digression: why do citizens get passionate about a DD outbreak? It would be nice to think they are passionate protectors of their trees, but I propose the rash and the mess on the car and the deck are the main motivators.

Whatever the cause, municipalities around Ontario have been besieged with calls to control DD outbreaks. BTK sprays are licensed in Canada. A survey I did in spring 2021 showed that many were contracting for spray applications. According to an interview by the CBC of a representative of one spraying company: "the company has committed to do aerial sprays for over 6000 individual contracts, eight municipalities and six reservations this year. He expects to cover about 50,000 acres of land throughout Ontario, ranging from municipal park lands, maple bushes, cottage areas and forestry woodlots."

The company is said to have sprayed four neighbourhoods of Sarnia on May 14 and 21 this year. Now, let's do a bit of ecological reasoning: BTK spray affects any lepidopteran caterpillar that eats it from tree leaves; the most favored species for DD moths are oaks; Douglas Tallamy has documented that oaks host more species and higher densities of caterpillars than any other genus of trees; Tallamy and many others have shown that caterpillars are the most common food of nestling birds; and the peak of nesting periods in Southern Ontario is from mid-May to June. Thus, it would appear that this spraying has drastically reduced baby food for birds in 50,000 acres of forest habitat in southern Ontario this year. I wonder if the passionate moth counters of the TEA have data before and after BTK spraying in specific Ontario locations.

Yet another digression*:* Bacteria are hard to put definitively into species buckets, because they promiscuously interchange DNA in the form of circular 'plasmids'. Research done on *B. thuringiensis* has shown that if you delete the plasmids encoding the gut toxin, it becomes nearly indistinguishable from the common soil bacterium *B. cereus*, and close to its kissing cousin *B.anthracis* (Koch, 1874) which causes anthrax.

Last digression, I promise*:* the DNA for BT toxin from *B. thuringiensis* plasmids has been transferred into genetically engineered crops such as corn, soy, and cotton. The plants themselves make the toxin. Bayer and Monsanto have patented these varieties. The side effects of this include insects which have evolved BT toxin resistance, such as pink bollworm (cotton), diamondback and cabbage looper moths (crucifers). BT toxin has been engineered into poplar trees which are widely used in plantations in China. The long-term effects of this on the forest Lepidopteran community are not yet known.

The Good: The City of Toronto's Urban Forestry division is proposing that for 2022 it would use the MNPV spray "BioVir." BioVir uses MNPV (short for multicapsid nuclear polyhedrosis virus), which so far as is known only attacks DD. Other moths and butterflies are said not to be affected. Other spray methods of control registered in Ontario use the bacterium BTK, which kills all moth and butterfly larvae that ingest it. One of the target areas is the Oak Savannah habitat in High Park. TEA has provided a letter of support to Toronto Urban Forestry for this use of the MNPV spray instead of BTK sprays.

High Park is an area of special environmental concern, containing one of the last Oak Savannah habitats in Ontario. Oaks are particular targets of DD moth. Losing the big old oaks in the savannah would be a huge environmental blow to the city and indeed to the province. I visited High Park numerous times this year and can testify to the large numbers of DD egg clusters on the trees this fall, suggesting a challenge next spring when they hatch.

A concern with the use of BioVir is that it has only conditional emergency registration for use in Canada. However, GypCheck, a product registered for control of DD in many US states, has the same MNPV active ingredient. GypCheck has been used for many years in the US, and has proven safe and effective.

Considerable testing work has been done with GypCheck to verify this. BioVir/GypCheck will not affect the many other species of caterpillars fed to baby birds. In fact, by reducing competition from DD caterpillars, it may increase the number of bird-friendly larvae to be fed to birds.

If the emergency use of BioVir in High Park is monitored and the effectiveness documented, it will give the many other areas in Ontario suffering from DD infestations hope for a biologically sound solution. I congratulate the City of Toronto's Urban Forestry division for proposing an ecologically safe and sound method of DD control. I hope this will go forward as planned.

I regard this as an ecologically safe and sound method of DD control, and I heartily endorse this proposal. But I'd like to suggest a caution: studies so far of MNPV spray haven't documented harm to other species. How many other tussock moth species have been tested?

The Unknown: The insect-eating fungi are a fascinating group. The genus name *Entomophaga* means just that: insect-eating. *E. maimaiga* is a Japanese fungus which attacks DD. "Maimaiga" is the Japanese word for DD moth. *E. maimaiga* was introduced in the Boston area 1910-1911, apparently without any effects. Several later introductions were tried, apparently unsuccessfully. But in 1989 DD caterpillar carcasses with *E. maimaiga* spores were found in the wild, and since then it has become an important control. According to Wikipedia: "*Entomophaga maimaiga* can only potentially affect lepidopteran larvae that are present in the spring, when gypsy moth larvae are present. 78 species which fit this criterion were

tested. Only about one-third were able to be infected under optimal conditions. Infection was only consistently high among three species of tussock moths and one colony of a hawk moth. However, field studies showed that rates achieved in the laboratory are far higher than found in the field."

As with MNPV, I'd like to suggest that fans of tussock, tiger, woolly bear, and underwing moths try to keep an eye on caterpillars for signs of fungal infections.

I hope you've enjoyed this journey through the entomology, ecology, and behaviour of disparate destructor moths and their kin and controls. As Andrewartha and Birch said in 1984, we need to pay attention to 'the ecological web' when we try to control nature.