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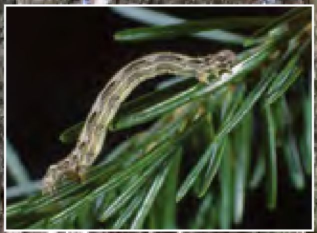
OF NATURAL RESOURCES CANADA



THE HEMLOCK LOOPER

Canada

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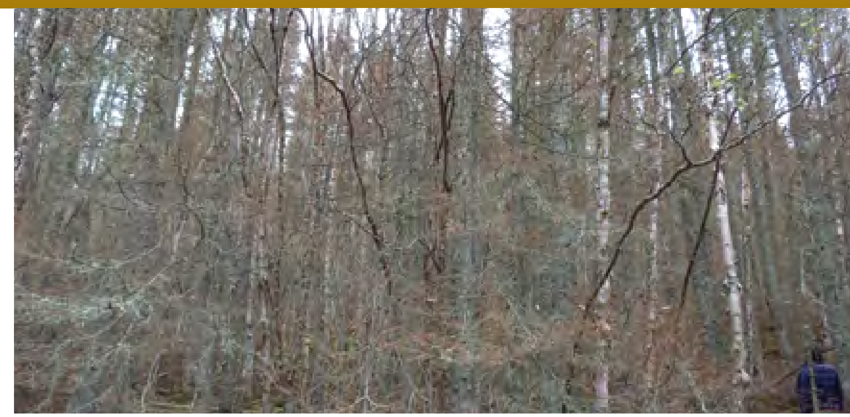
The hemlock looper (*Lambdina fiscellaria*) is a native species found across Canada, and it is considered a serious defoliator. It gets its name from its characteristic walking motion: the larva, which only has legs at either end of its body, moves by thrusting its front legs forward and then dragging the end of its body. The Canadian Forest Service (CFS) has been conducting research on this species for a number of years in order to gain insight into its life cycle, understand its population dynamics, and improve detection and control methods.

WASTEFULNESS THAT MAKES YOU SEE RED

The main host of the hemlock looper in eastern Canada is the balsam fir, while in western provinces, it is the Western hemlock. Loopers feed on needles, only nibbling part of a needle before moving on to another. Toward the end of July or early August, needles that are partially eaten by the larvae dry out and turn red. Infested trees take on a reddish colour that is very characteristic of hemlock looper outbreaks.

Because populations increase suddenly, they can cause the death of firs within the first year that damage is detected. Surviving trees show a marked decrease in radial growth for several years after an outbreak. Partial defoliation weakens trees, making them vulnerable to diseases and attacks by secondary insects. By analyzing tree-ring data, researchers can reconstruct the history of infestations.

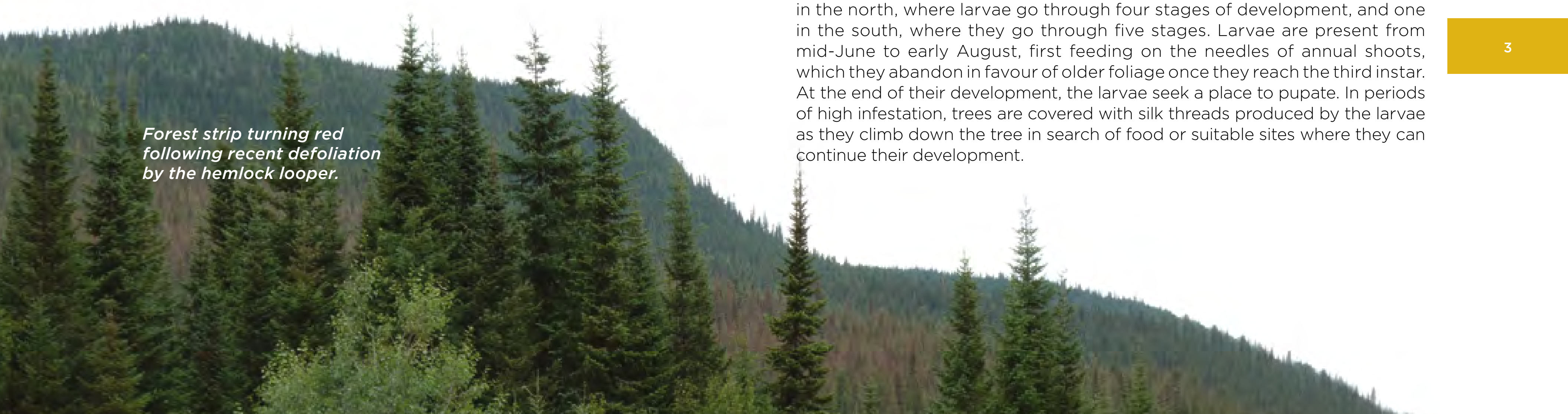
Of course, hemlock looper damage can be calculated in terms of wood volume loss. However, other less readily quantifiable values should also be taken into consideration, including landscape quality, recreation and tourism potential, and environmental quality for populations living in outbreak-affected areas.



During a severe outbreak, the hemlock looper does not single out mature firs; it also attacks hardwoods and other conifers, including saplings and seedlings.

A YEAR IN THE LIFE OF THE HEMLOCK LOOPER

The hemlock looper overwinters at the egg stage. The eggs hatch in late spring, shortly after fir budbreak. There are two types of looper, one found in the north, where larvae go through four stages of development, and one in the south, where they go through five stages. Larvae are present from mid-June to early August, first feeding on the needles of annual shoots, which they abandon in favour of older foliage once they reach the third instar. At the end of their development, the larvae seek a place to pupate. In periods of high infestation, trees are covered with silk threads produced by the larvae as they climb down the tree in search of food or suitable sites where they can continue their development.



Forest strip turning red following recent defoliation by the hemlock looper.

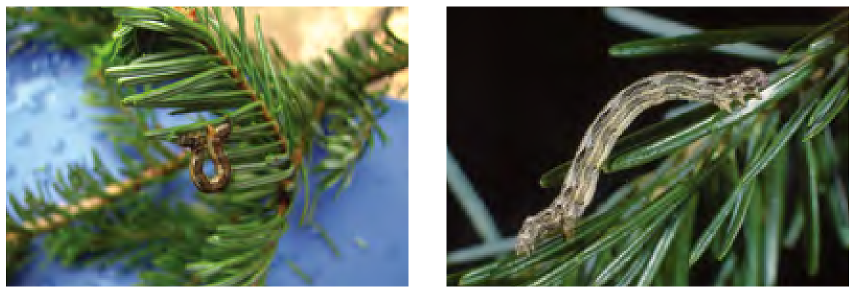
The adult beige moth emerges from the chrysalis in mid-August. After mating, females lay their eggs on tree trunks, branches, dead trees, and sometimes even on the ground. If the eggs are laid in less exposed locations than branches - for example, at the base of the trunk or on the ground surface, where the snow cover provides protection against the cold - larval density the following spring may be higher than what was expected based on egg sampling on branches.

CFS researchers are continually increasing their knowledge of the looper's biology, which seems to benefit from the new conditions created by global warming. Thus, they continue their research in order to understand the impact of these changes on the insect's survivability and time to hatching, on the duration of larval development as well as on the mating success and fertility of females.

Eggs in an ovary.

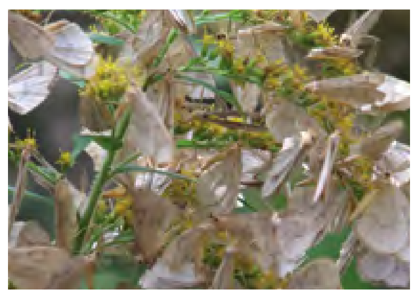
Hemlock looper exiting its egg.

The eggs, which are green when laid, turn coppery brown when fertilized.



Hemlock looper larva.

Moths mating.

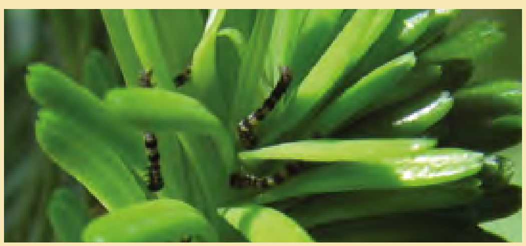


Male moths on Canada goldenrod flowers.

Moth.

HATCHING: AS REGULAR AS CLOCKWORK

In spring, the eggs all hatch at the same time, even if they were not laid at the same time. This phenomenon occurs through diapause. Diapause is an adaptation method that allows insects to escape unfavourable environmental conditions that would threaten their survival, such as the onset of winter. This process is characterized by developmental arrest and a lower basal metabolism. Diapause includes three phases: pre-diapause, diapause and post-diapause. At the post-diapause stage, eggs become quiescent, which means they are physiologically ready to continue their development, but are unable to do so due to temperatures that are too cold. It is during this phase that eggs become synchronized. Indeed, no matter how long it took for them to get there, they will resume their development all at the same time as soon as temperatures begin to rise in the spring.



Synchronized hatching of hemlock loopers.

Hemlock looper egg in diapause.

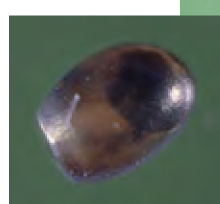
POPULATION DYNAMICS

Looper outbreaks appear and disappear suddenly. Small defoliated areas are scattered over a large territory in the first year of infestation. In the second year, the infestation spreads and affects a larger area. In Quebec, an invasion rarely lasts more than two or three years. The damage is greatest when loopers prey on pure, mature or over-mature fir stands.

Between 1910 and 1975, the looper caused losses that have been estimated at 12 million cubic metres of wood in Newfoundland and 24 million cubic metres of wood in Quebec. Other outbreaks have occurred since then in Quebec, particularly in the Lower St. Lawrence, Gaspe Peninsula and Anticosti Island regions, and more recently, in the North Shore and Quebec City regions. The last epidemic in the North Shore region, which occurred in the early 2000s, has reportedly caused losses estimated at 15 million cubic metres of wood. CFS researchers have gathered the necessary data to develop a tool to identify the areas that are the most at risk of infestation based on climate. Based on this information, forest managers can monitor these areas and intervene in a timely manner.

Several natural enemies, including insect parasitoids, play an important role in population dynamics. Working in collaboration with forest sector partners, CFS researchers have identified the key role played by parasitoids of the genus *Telenomus* which attack looper eggs, primarily in the spring, and which have caused the collapse of a predicted outbreak in the Gaspe Peninsula in the late 1990s and of another in the North Shore area in 2001. The researchers are now studying the life cycle and attack behaviour of these parasitoids to assess their potential as biological control agents.

Dorsal side of a Telenomus *pupa in a hemlock looper egg.*

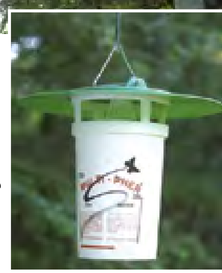


Telenomus *(adult female, about 0.8 mm long).*

INNOVATION AND COLLABORATION TOWARD BETTER DETECTION

Since the 1990s, CFS researchers have developed various tools to detect the hemlock looper, such as light traps and pheromone traps as well as oviposition and pupation sites. The data collected using these tools, coupled with aerial surveys, are used to monitor population trends over the sampled area. However, this area only represents a small percentage of the potential food supply available to the hemlock looper. This is when it becomes necessary for everyone, from people working in the field to tourists, to be on the lookout. By providing them with more information on the insect and the signs of its presence - such as the flight of moths in September or the gathering of moths on flowers - they will contribute to a better coverage of the territory and ensure the necessary monitoring over a longer period of time.

Light traps.



Pheromone trap.

Oviposition site.

Trap saturated with insects.

TO INTERVENE OR NOT TO INTERVENE, THAT IS THE QUESTION

In Quebec, the insect is monitored by the ministère des Forêts, de la Faune et des Parcs (MFFP), and the Société de protection des forêts contre les insectes et les maladies (SOPFIM) intervenes when necessary. During major epidemics, a *Bacillus thuringiensis* var. *kurstaki* (*B.t.k.*) aerial spraying program is implemented. This was the case in 2000, when 40,000 hectares of forests were treated in the North Shore area. When severely defoliated areas are restricted, it is possible to recover the stands under attack.

Through their work, CFS researchers contribute to the development of a predictive seasonality model for the looper.

IS EXTREME COLD A THREAT?

The frequency and intensity of extreme weather events are expected to increase with climate change. Insects will therefore need to adapt in order to cope with sudden temperature changes. Researchers from the Canadian Forest Service and Université Laval have been studying the cold tolerance of hemlock looper eggs and its impact on the insect's population dynamics. They found that looper eggs freeze at an average temperature of -40°C. However, determining this freezing point is not a method that is as reliable and realistic as conducting cold tolerance tests when it comes to estimating the likelihood of survival of looper eggs. Indeed, the eggs may die from the cold or from freezing long before the air temperature reaches -40°C.

This is what happened in January 2013 when two cold snaps occurred within the entire Laurentides Wildlife Reserve and its surroundings, with temperatures dropping to -35/-36°C during about 6 hours. These cold snaps caused a significant drop in the looper population, which had exploded dramatically in 2012, before being completely decimated in 2014. Following a first cold snap that occurred in 2009 in the same geographic area, it had only taken three consecutive mild winters followed by a warm, dry spring to cause a meteoric rise in the looper hemlock population.

This demonstrates the extreme vulnerability of hemlock looper eggs to intense cold snaps, even if they only last a few hours per day. This vulnerability could limit the survival of looper populations in northern and inland areas. However, climate change models predict that the frequency of winters with such lethal temperatures will decrease. This could lessen temperature constraints at the northern limit of the insect's range and make it possible for infestations to expand toward the north and inland.

Thermal probe attached to the egg surface (inset), and assembly used to determine the freezing point of several eggs simultaneously.

Temperature monitors programmed to take readings every 15 minutes in order to detect sudden changes in temperature.

Pupation site.
Eggs on styrofoam disc placed inside a sticky trap to study their winter survival in the forest.

Eggs bottled and placed in a freezer to study their cold tolerance.

ANOTHER CHALLENGE TO OVERCOME: HEAT

Due to the longer growing season under warmer climate conditions, insect development and reproduction will occur more quickly. Studies conducted by CFS researchers have shown that prolonged exposure of eggs to warmer than normal temperatures increased their likelihood of dying prematurely. So how will adults react to warm temperatures if they emerge earlier in the season? Recent studies have shown that temperatures above 25°C disrupt mating and significantly reduce female fecundity and egg fertility. To overcome these negative effects, the looper would benefit from reproducing later in the season, by extending the duration of its larval development.

FAST FRIENDS?

The looper and the spruce budworm share a common attraction to spruce and fir. However, they each have their own favourite parts: the budworm favours buds and annual shoots, while the looper prefers both young and old needles. The hemlock looper eats later in the season than the spruce budworm, and can decimate a forest three times as quickly.

Useful links

Trees, insects and diseases of Canada's forests: https://tidcf.nrcan.gc.ca/en/insects/factsheet/8846

"Using scents to trap forest insect pests": http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/28316.pdf

"Hemlock looper egg hatching: regular as clockwork": http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/31713.pdf

About parasitoids: http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/25080.pdf and http://cfs.nrcan.gc.ca/entrepotpubl/pdfs/33423.pdf

On the effects of temperature: http://cfs.nrcan.gc.ca/entrepotpubl/pdfs/36493.pdf

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