The HEMLOCK LOOPER

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Cover

Photo 1
Mature hemlock looper larva
(Photo: *T. Arcand*)

Photo 2
Severely defoliated trees
(Photo: *L. Jobin*)

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Taxonomy

The hemlock looper, *Lambdina fiscellaria* (Guenée), is an indigenous Lepidoptera of North America which belongs to the Geometridae family. Caterpillars (also called larvae) of this family lack the abdominal prolegs borne in the middle of the body by other Lepidoptera, and have only two (some species have three) pairs of prolegs at the posterior end of the body. Locomotion is achieved by throwing their anterior end forward, grasping onto something using their anterior legs and then pulling up the posterior end of their body. Then, the middle portion of the larva bends upward, forming a loop. Their common name (also called measuringworm) comes from this characteristic fashion of moving.

Long considered to be subspecies, the looper found in eastern Canada (*L. fiscellaria fiscellaria*) and the looper found in western Canada (*L. fiscellaria lugubrosa*) are now recognized as a single species (McGuffin 1987; Raske et al. 1996; Sperling et al. 1999).

Hosts and Distribution

The hemlock looper is distributed across Canada, in the Great Lakes States and as far south as Georgia in the eastern U.S., and in Washington, Idaho, Montana and Oregon in the west. Occurrences of this species have also been recorded in southeastern Alaska. However, the information in this leaflet concerns essentially the hemlock looper in eastern Canada.

In eastern Canada, the hemlock looper feeds on many forest tree species but damage has been reported mostly on balsam fir (*Abies balsamea* [L.] Mill.) and eastern hemlock (*Tsuga canadensis* [L.] Carr.). When populations reach epidemic proportions, this insect usually severely defoliates companion species such as white spruce (*Picea glauca* [Moench] Voss), black spruce (*Picea mariana* [Mill.] BSP) and white birch (*Betula papyrifera* Marsh.). Even eastern white cedar (*Thuya occidentalis* L.), white pine (*Pinus strobus* L.) and trembling aspen (*Populus tremuloides* Michx.) have been reported to be defoliated in some infestations in Ontario (Howse and Applejohn 1994). Other potential host species include tamarack (*Larix laricina* [Du Roi] K. Koch), sugar maple (*Acer saccharum* Marsh.), yellow birch (*Betula alleghaniensis* Britton), white elm (*Ulmus americana* L.), cherry (*Prunus* sp.), and even jack pine (*Pinus banksiana* Lamb.).

PREVIOUS OUTBREAKS

The most severe outbreaks of this insect have occurred in eastern Canada, mainly in Newfoundland and Quebec where numerous outbreaks were reported in the 20th century (Benoit and Desaulniers 1972; Otvos et al. 1979; Jobin 1980; Hudak et al. 1984; Bordeleau 1991-1999). Infestations in Ontario and the Maritime provinces were of short duration and mostly restricted to small areas.

In Quebec, Watson (1934) observed and studied the first outbreak of the looper on the North Shore in 1927. However, growth ring analysis showed that an outbreak had occurred some years earlier (in the 1920s) on Anticosti Island (Jobin 1980); it would have been followed by another more destructive outbreak, again on Anticosti Island, during the 1930s (Jobin 1980). Many infestations occurred subsequently, notably in the Gaspé Peninsula in 1936 and 1946, where more than 40 000 ha of forest was completely destroyed (Benoit and Desaulniers 1972; Jobin 1980). On the North Shore, a new outbreak was reported in 1956 (Benoit and Desaulniers 1972; Jobin 1980; Pilon 1997), and then in the early 1970s a particularly severe infestation swept across Anticosti Island, encompassing more than 220 000 ha and destroying at least 80 000 ha of forest (Jobin and Desaulniers 1981). This outbreak also affected nearly 16 000 ha of forest in the North Shore region. In the early 1990s, less extensive infestations were reported in the Lower St. Lawrence region (Parke Reserve) and on Anticosti Island (Bordeleau 1991-1999). An aerial survey conducted in the summer of 1996 by Quebec's ministère des Ressources naturelles located 7 850 ha of defoliated forest in the eastern part of the Gaspé Peninsula (Bordeleau 1991-1999). Through an egg survey, it has been possible to delimit zones encompassing more than 330 000 ha where the hemlock looper populations had reached epidemic levels (Bordeleau 1991-1999). The infestation turned out to be much less extensive than anticipated, with only 21 770 ha undergoing defoliation in 1997 (Bordeleau 1991-1999). During the summer of 1998, over 27 000 ha of defoliated forests were reported on the North Shore (Bordeleau 1991-1999). However, contrary to the Gaspé outbreak two years earlier, this incipient outbreak progressed rapidly and reached major proportions in 1999 with 472 000 ha of defoliated forest (of which 95% were severely defoliated; Bordeleau 1991-1999) and in 2000 with 925 000 ha of defoliated forest (Bordeleau, pers. comm.). This is undoubtedly the most severe outbreak of the hemlock looper ever recorded in Quebec.

Concurrently with infestations occurring in Quebec, between 1989 and 1993, New Brunswick faced its first hemlock looper outbreak, which necessitated action to protect just over 21 000 ha of forest in 1990 (Hartling et al. 1991). The State of Maine, which had never before been seriously impacted by this insect pest, also had to come to grips with severe infestations that covered nearly 100 000 ha in 1991 (Trial 1993).

The Hemlock Looper's Development Stages

Egg:

Ovoid and about 0.90 mm long, the egg has a truncate end and a reticulate structure. The egg is light green at deposition and turns coppery brown after a few days (*Figure 1*); sterile eggs remain greenish in colour.

Figure 1

Hemlock looper eggs on epiphytic lichens (Photo: *C. Germain*)

Larva:

The larva has the characteristic form of looper larvae, with two pairs of prolegs at the posterior end of the abdomen. A few hours after eclosion, the young larva (*Figure 2*) is a dark gray colour with black crossbands that give it a segmented appearance. As the larvae mature, they take on various colours, ranging from yellow to black (*Figure 3*).

Figure 2

Young hemlock looper larva (Photo: *T. Arcand*)

Figure 3

Mature hemlock looper larva and partially eaten foliage typifying this insect's wasteful behaviour (Photo: *T. Arcand*)

Pupa:

Spindle-shaped, with colour varying from beige with brown spots to dark brown. About 20 mm long (*Figure 4*).

Figure 4

Pupae of the eastern hemlock looper (Photo: *T. Arcand*)

Adult:

Figure 5

Moth of the eastern hemlock looper (Photo: *L. Jobin*)

The adult is a moth with a wingspan of about 32 mm; it varies in colour from beige to brownish gray (*Figure 5*). Its forewings are crossed by two purplish broken lines and the hindwings by a single line. The male is easy to recognize with its feathery antennae and narrow abdomen, in contrast with the female, which has thread-like antennae and a rounded abdomen.

Life Cycle and Behaviour

The hemlock looper has only one generation per year and overwinters in the egg stage. The eggs are generally deposited on host trees, either on the trunk or on branches, although many of them are also dispersed elsewhere, on birches, snags and the sphagnum moss cover (De Gryse and Schedl 1934; Watson 1934; Carroll 1956). The presence of eggs is strongly associated with the abundance of epiphytic lichens (Jobin 1973). The eggs hatch late in spring, shortly after budbreak in balsam fir, and the young larvae are then dispersed by the wind. The larvae initially feed on new foliage, but midway through their development they migrate toward the older foliage (De Gryse and Schedl 1934; Watson 1934; Carroll 1956). Recent work showed that feeding on new foliage was essential for survival of young larvae but also that feeding on old foliage by late instar larvae increased insect survival and fecundity (Carroll 1999). The larval feeding behaviour is wasteful since they sever needles at the base or merely chew on the needles without eating them completely. The larvae move about freely on the foliage and are often cast to the ground during heavy rains or high winds (De Gryse and Schedl 1934; Trial 1993).

Hemlock looper larvae go through four instars in Newfoundland (Carroll 1956) and on Anticosti Island (Jobin and Desaulniers 1981) compared with five instars in Ontario (De Gryse and Schedl 1934) and New Brunswick (Hartling et al. 1991). In Eastern Quebec, larvae are present primarily between mid-June and early August. Toward the end of their development, the larvae begin seeking a pupation site. During periods of heavy infestation, the trees are covered with silk threads produced by the larvae as they descend in search of food or a place to pupate (*Figure 6*). Like the eggs, the pupae are dispersed in the environment. They are frequently found on host trees, either in bark crevices, under strips of bark or in lichens (Watson 1934). Trees with smooth bark contain few pupae compared with those with rough bark (De Gryse and Schedl 1934). Some authors have reported finding a large number of pupae in old stumps (Carroll 1956; Jobin and Desaulniers 1981) and in the angles formed by roots at the base of tree trunks (De Gryse and Schedl 1934).

The pupal stage lasts about 16 to 20 days. The adults emerge between late August and early October, with the males preceding the females by a few days (Carroll 1956). During the first night, the female shows calling behaviour associated with sex pheromone release (West and Bowers 1994). The moths are not strong fliers (Watson 1934) and the males are active mainly at dusk; the females are not very active except after half of their eggs have been deposited (Delisle et al. 1998). Mating is observed mainly on the boles of host tree species, and the females deposit their eggs singly or in small groups of two or three, mostly during September. The height above ground at which egg-laying occurs is influenced by weather conditions; females are believed to lay their eggs on the ground and in old stumps when the weather is cold, wet and windy, whereas during warm, calm periods, eggs are laid higher up, in the tree crown (Otvos et al. 1971). The females live for 20 to 25 days and lay 100 to 300 eggs.

Figure 6

Defoliated trees covered with silk threads around the end of larval development (Photo: *C. Hébert*)

Epidemiology and Natural Control

Hemlock looper outbreaks begin and end very suddenly (Watson 1934). They develop at an incredibly fast rate, and can even kill balsam fir during the first year in which damage is detected (Watson 1934; Jobin and Desaulniers 1981). Outbreaks are characterized by small pockets of infestation scattered over a vast area (Carroll 1956; Otvos et al. 1979). Regenerating trees are often affected to a greater extent than mature trees during the first year of the outbreak, and uninfested areas are frequently found next to severely impacted zones (Watson 1934). In New Brunswick, MacLean and Ebert (1999) reported a 22-48% higher mortality on trees of small diameter (< 11 cm) than on larger trees. During the second year of outbreak, the pockets of infestation increase both in number and areal extent, eventually joining to form huge expanses of defoliated forest with irregular margins. The infestation is especially severe when 70% or more of the infested stands consist of mature or overmature hemlock or balsam fir (De Gryse and Schedl 1934; Carroll 1956). Hemlock looper infestations often occur in stands situated near bodies of water, indicating that this pest is associated with a maritime climate (Jobin 1973, 1980).

Figure 7

Telenomus sp., an important egg parasitoid (Photo: *C. Germain*)

The factors involved in the abrupt onset and end of infestations have not been studied much to date. Nonetheless, several natural enemies play an important role in controlling hemlock looper populations. Many parasitoid species attack different life stages of this pest (Otvos 1973). The magnitude of the outbreak predicted in the Gaspé Peninsula in 1997 was considerably reduced owing to the activity of an egg parasitoid that belongs to the genus *Telenomus* (Hébert et al. 2001) (*Figure 7*). A number of parasitoids infest looper larvae, and most of them emerge from the host around the end of larval development or during the pupal stage. One species of *Apanteles* (Hymenoptera: Braconidae) sometimes has a considerable impact (Carroll 1956); however, the most important role is played by a species of the order Diptera (Tachinidae): this fly species, *Winthemia occidentis* (*Figure 8*) lays its eggs on mature larvae, and its larva emerges from the pupa. Pupae, too, are parasitized by a number of Hymenoptera (Ichneumonidae) species, with the key ones being *Itoplectis conquisitor* (*Figure 9*) and *Aoplus velox*. Also, many hyperparasites infest primary parasitoids. In addition, a number of bird species are predators of the hemlock looper, particularly of the larval and pupal stages. However, their impact on looper populations is difficult to measure (Otvos and Taylor 1970).

Figure 8

Winthemia occidentis, a tachinid fly which deposits its eggs on mature larvae and emerge from pupae (Photo: *C. Germain*)

A number of entomopathogenic micro-organisms infect the hemlock looper. A nuclear polyhedrosis virus and a microsporidium of the genus *Nosema* have been found on Anticosti Island (Smirnoff and Jobin 1973). However, two fungal species, *Entomophthora sphaerosperma* and *Entomophaga aulicae*, have more often been linked to declines in looper populations (Jobin and Desaulniers 1981; Otvos et al. 1973). These fungi infect both young and mature larvae, but have a greater impact at the end of larval development (Carroll 1956; Otvos 1973). More recently, Clopton and Lucarotti (1997) and Lucarotti et al. (1998) found and described a new species of protozoa of the Eugregarinida order, *Leidyana canadensis*, associated with an outbreak collapse in New Brunswick. However, it has not been possible to evaluate the real contribution of this protozoa to the outbreak collapse.

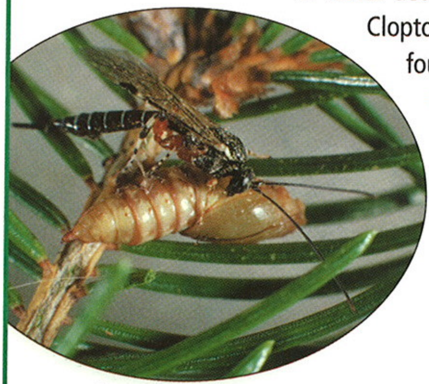

Figure 9

Itoplectis conquisitor, an Ichneumonid attacking a pupa (Photo: *C. Germain*)

DAMAGE and IMPACT

Figure 10

Defoliation typical of the hemlock looper (Photo: *L. Jobin*)

In late July and early August, the trees take on a reddish colour that is highly characteristic of hemlock looper outbreaks. It is the hemlock looper's wasteful feeding behaviour that makes it such a formidable defoliator (*Figure 10*). After coniferous needles have been chewed on, they dry out and redden, eventually falling in the autumn (Watson 1934). The infestations can be quite devastating (*Figure 11*). According to Bhiry and Filion (1996) who studied needle remains and head capsules found in peat moss, the hemlock looper is associated with a decline of eastern hemlock that occurred in the mid-Holocene period.

In the case of the New Brunswick infestation, MacLean and Ebert (1999) reported a low mortality (<1%) for trees having total defoliation <50% but mortality reached 92% for trees suffering from ≥90% of total defoliation. Between 1910 and 1975, looper outbreaks caused losses estimated at 12 million m^3 of timber in Newfoundland (Otvos et al. 1979) and at 24 million m^3 in Quebec (Jobin 1980). Trees that survive an outbreak show important radial growth reduction (up to nearly 50%) during the two or three years of defoliation (Martel 1999). Radial growth recovery is usually spread over a period of similar duration.

Figure 11

Terrestrial view, 25 years later, of a stand that has suffered severe mortality due to defoliation by hemlock looper in 1972 on Anticosti Island (Photo: *C. Hébert*)

A decision support system for this insect pest was developed and tested in Newfoundland in the early 1990s. Designed for predicting defoliation, the system is composed of models developed from historical data. Under current conditions, however, the system is not very useful since it greatly underestimates the level of damage (Carroll 1996). According to the author, models devised from historical records do not permit accurate prediction of the course of an infestation because of the major changes that have occurred in the forest landscape during recent decades.

Detection and Monitoring

Until the early 1990s, aerial damage surveys and foliage beating samples taken to estimate the size of larval populations were the main methods used for detecting and making predictions about hemlock looper populations. Over the past few years, a number of methods and tools have been developed to improve detection and prediction strategies. The sex pheromone of the looper has been identified and synthesized (Gries et al. 1991), and pheromone trap monitoring networks are now operating in all high-risk regions of northeastern North America. Although the pheromone has a strong potential for attraction and that it seems to provide satisfactory results in British Columbia (Evenden et al. 1995a, 1995b; Liang et al. 1997), trapping has so far not allowed researchers to predict population levels with a satisfactory degree of accuracy in Quebec. Surveillance now also involves assessing the egg populations of this pest. In eastern Canada, 1-m-long branches are sampled (Dobesberger 1989), whereas in the west sampling involves collecting a pre-determined weight of lichens from the tree canopy (Shore 1990; Liang et al. 1996). These samples undergo an egg extraction process in the laboratory (Otvos and Bryant 1972; Shepherd and Gray 1972; Shore 1990). In Quebec, damage forecasts based on this method have been often inaccurate. However, in the State of Maine, satisfactory results have been obtained (Trial and Trial 1992).

New tools have also been developed over the past 5 years at the Laurentian Forestry Centre of the Canadian Forest Service in Sainte-Foy, Quebec, including a pupation shelter (*Figure 12*) and an oviposition trap (*Figure 13*). Pupation shelters

Figure 12

Shelter used for sampling pupae (Photo: *C. Hébert*)

Figure 13

Oviposition trap (styrofoam strip) for sampling hemlock looper eggs (Photo: *C. Hébert*) are used to evaluate looper populations at the pupal stage and assess the effect of natural enemies on the monitored populations. The first pupation shelter was developed by Otvos (1974) and used also by Shore (1989) and Liang et al. (1998) in British Columbia to evaluate pupal populations. On the other hand, the oviposition trap is simply made of a piece of polyurethane foam placed on a tree bole; it is very simple and permits rapid assessment of egg populations. These new tools are standardized, simple and can be applied by persons without a specialized background. This makes it possible to operate a larger number of monitoring sites, a crucial point in detecting hemlock looper outbreaks, and ensures more effective surveillance. These tools' capacity to predict hemlock looper damage is currently being evaluated; however the integration of an index of activity of *Telenomus* (egg parasitoids) would help to increase the accuracy of predictions.

Control Measures

In the case of a severe infestation confined to small areas, the infested stands and adjacent ones can be harvested during the winter, even when major losses are anticipated (Québec, Ministère des Forêts 1991). Residual populations (eggs on the ground or remaining on debris or birches) have a low chance of surviving because after egg hatching, young larvae must spend large amounts of energy to find food, which is not abundant and often of low quality. During a major outbreak, since salvage cutting cannot be done in all stands simultaneously, direct control measures are necessary. Until the early 1980s, fenitrothion was the main registered insecticide used on an operational basis against the hemlock looper (Prebble 1975; West et al. 1989). This insecticide was also employed in New Brunswick to control looper populations in 1990-1991 (Hartling et al. 1991). However, over the past 10 years or so, the biological insecticide *Bacillus thuringiensis* var. *kurstaki* (*B.t.*) is the product that has been used most often against the hemlock looper (West et al. 1989, 1997). *B.t.* spraying is usually done at the beginning of the second larval instar, when egg hatching is completed. In the case of a highly severe outbreak, a second *B.t.* application may be made. The positive or negative impact of *B.t.* applications on larval and pupal predators and parasitoids of the looper is unknown. However, as egg parasitoid populations usually increase during an outbreak, it is possible that while reducing looper populations, *B.t.* applications may favour egg parasitoids in the next looper generation.

The possibility of introducing exotic parasitoids to strengthen the complex of natural enemies in Newfoundland has been evaluated recently, but without success (West and Kenis 1997). Work has also focused on developing a technique for mass rearing of the fungus *Entomophaga aulicae* (Nolan 1993). Moreover, studies are continuing in an effort to characterize and evaluate the pathogenicity of various natural strains of virus (Levin et al. 1997).

As for the eastern spruce budworm, harvesting old stands has been recommended to reduce the risk of infestation by the hemlock looper (Martineau 1984). However, such a strategy should be examined carefully before being used because of the increasing importance being given to old-growth forests for conserving biodiversity (Desponts et al. 2000; Martikainen et al. 2000), a criterion used to measure our progress towards sustainable development.

For Further Information

Anyone with comments or suggestions regarding the information provided in this leaflet is invited to contact the authors by e-mail at chebert@cfl.forestry.ca.

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