Insects of Seed Cones
IN EASTERN CANADA

FIELD GUIDE

Ontario Canada

Insects of Seed Cones in Eastern Canada

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PREFACE

Insects of seed cones in eastern Canada is a revised version of the field guide "Management of insect pests of cones in seed orchards in eastern Canada". The title of the guide was changed to reflect a shift in emphasis. The objective of the original version was to provide seed orchard managers with the fundamental, but essential, information necessary to optimize seed production by maintaining the most common insect pests encountered in coniferous seed orchards at tolerable levels. The switch in emphasis was necessary because at the time the original guide was published, in 1992, the components of an insect pest management system in eastern Canada seed orchard had not been fully developed yet. Nonetheless, there was a critical and urgent need to introduce these systems immediately to users in a simple and concise manner with the understanding that it would pave the way for the more comprehensive and fully operational cone crop monitoring system that was being developed. This monitoring system has now been published elsewhere (de Groot *et al.* 1995, 1996, 1998). Thus, a guiding principle for this revised version has been to shift away from the pest management emphasis of the original version and to focus on the biological information available on the communities of insects infesting this resource, whose abundance fluctuates greatly in time and space. In addition, the biological information generated through research in the past decade is presented and the number of native conifer genera treated is increased from 3 to 5: balsam fir and eastern hemlock have been added to eastern larch, spruces and pines.

Insects of seed cones in eastern Canada is written to assist seed collectors, foresters and seed orchard managers and other non-entomologists from northeastern North America in general, and from Ontario in particular, to detect, recognize and identify insects associated with this resource. Although the look of this guide has changed, its dimensions have been retained to ensure that it can be taken to, and used in the field. At the same time, it can be incorporated easily into the binder "A seed manual for Ontario", which contains the latest version of "Guidelines for tree seed crop forecasting and collecting".

Insects of seed cones in eastern Canada has been divided into 5 sections. The first section contains general information on the diversity and ecology of the insect communities associated with seed cones of these hosts. It begins with definitions and examples of the various categories of associations, patterns of resource utilization (or guilds) and groups of life cycles specific to this insect fauna. Also presented is a new section providing a synopsis of the relationship between insects and seed cones. Also new is a section on our current knowledge on how insect find and select cones for feeding or egg laying.

The second section is a simple key combined with a photographic aid that has been proven during the past decade to provide speedy and, for the most part, reliable identification of the insects damaging cones and seeds of balsam fir, eastern larch, spruces, pines and eastern hemlock. The keys follow the process of examination and handling of cones one would undertake under field conditions: that is 1), determine whether the exterior of the cone is damaged; and 2), bisect the cone to determine whether the inside is damaged.

For each step, there is often several possible causal agents. The most common types of damage one would encounter under field conditions have been described. Each description is coupled with a colour photograph illustrating, as closely as possible, the damage one would see whether the insect is present or absent. This section should facilitate and expedite pest identification, especially by non-entomologists.

The third section provides a summary of the biological information available on these insects. It includes taxonomic and morphological information available for most insects listed in the key to damage, as well as essential information about the geographic distribution, life history, damage, economic importance, monitoring tools and management options currently available.The delivery of information in point form has been maintained to minimize the amount of reading necessary to obtain the desired details or facts.

The fourth section describes some simple methods that seed collectors can use in natural stands to assess cone crops for insect damage whereas the fifth section describes a formal method to assess the quantity and quality of a cone crop in a seed orchard. A brief introduction to CONESYS is provided. CONESYS consists of three modules: 1) the Cone Crop Monitoring System, which provides data on the size of the cone crop and expected damage at various times through the development of the cone crop; 2) the Information Management System, which provides information on the biology and damage from insects, and control products available and expected efficacy, and 3) the Decision Support System, which provides costs and benefit calculations for various pest control options. This section illustrates how pest management can be integrated into a crop management program (cone crop monitoring system) without a duplication of efforts. Also this information should facilitate effective use of the information provided in section 3.

It is hoped that with all these transformations and improvements, **Insects of seed cones in eastern Canada** will remain the most widely consulted reference for easy to access information on insects infesting seed cones of conifers native to northeastern North America.

PREFACE TO FIRST EDITION

Management of insect pests is only one of the many tasks associated with the production of genetically improved seeds. To date, the information provided on insect pest management in seed orchards has usually been limited to the introduction of the major pests and to a list of the pesticides available for population suppression. Insect pest management is much more complex than that and must also be integrated into the resource management scheme of the orchard. Effective and rational pest management requires an accurate identification of the pest, a basic understanding of its biology, methods to monitor its presence and evaluate its abundance, as well as tactics and strategies to prevent or control damage. This guide provides seed orchard managers with fundamental, but essential, pest management information on the most common insect pests encountered in coniferous seed orchards in a simple, concise and comprehensive manner.

This guide is divided into 3 sections. The principle components of seed orchard pest management are presented in the first section. It includes a chapter on the development of a cone crop monitoring system, followed by chapters on general guidelines and methods for monitoring, assessing impact, preventing and controlling cone and seed insects. This section illustrates how pest management can be integrated into a crop management program (cone crop monitoring system) without a duplication of efforts. Also this information should facilitate effective use of the information provided in sections 2 and 3.

The second section is a key to identify damage caused by cone and seed insects of larch, pine and spruce. The keys are accompanied by pictures illustrating, as closely as possible, the damage observed under field conditions. This section should facilitate and expedite pest identification by non-entomologists.

All information currently available on the distribution, general description, life history, damage and management options of the most common cone and seed insects is synthesized in the third section. Tables indicating the feeding periods or the time insects attack their host in relation to host phenology are included. This information should provide a sound basis for pest management decisions.

Sections of this guide will be updated when new knowledge of the biology and management of insect pests of coniferous seed cones is obtained.

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INSECT COMMUNITIES OF SEED CONES

The seed cone as a habitat

Before addressing the issue of diversity and structure of insect communities associated with **seed cones**[1], it is essential to describe this habitat. Most seed cones consist of a main axis bearing spirally arranged bract/fertile ovuliferous scales (Figure 1). Each bract associated with an ovuliferous scale, which bears exposed seeds, is joined at the base to the cone **axis**. Because of the diversity of their characteristics (bract, dwarf-shoot, ovules, seed wing, aril), seed cones vary in length (0.2 cm - 60 cm), shape, and colour. Thus, each seed cone represents a discrete microhabitat.

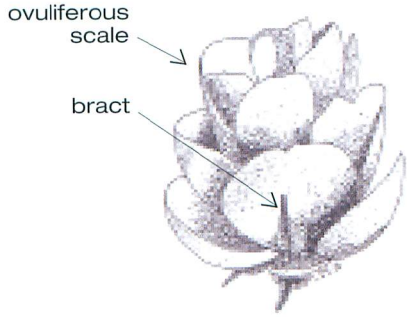


Figure 1. Seed cone

Seed cone development, which is extremely rapid especially when compared to tree life, is characterized by significant morphological and biochemical transformations. The reproductive cycle of conifers in general is broadly similar and can be summarised as follows: 1, reproductive buds are initiated in the growing season preceding the spring in which seed cones become externally visible; 2, seed cone buds burst open at specific periods to receive pollen, which is carried by wind; 3, the time between pollination and fertilization varies from a few days to several months, depending on the type of reproductive cycle; 4, following fertilization, cones develop rapidly at first and mature slowly; and 5, seeds disperse immediately or shortly after cones lignify – although some species don't shed their seeds for several years. The most notable difference is in the duration of the cycle (i.e., time between reproductive bud initiation and seed maturity). In some Pinaceae, such as in species of *Abies, Larix, Picea* and *Tsuga*, the cycle lasts 2 years: pollination of the seed cone and cone maturation both occur during the same year, the year after bud initiation (i.e., year 2). In other Pinaceae, such as *Pinus* spp., the cycle lasts three years: pollination also occurs during year 2, but development stops shortly after pollination, in mid-summer, and fertilization occurs in year 3, shortly after seed cone development resumes in the spring. In this case, cone maturation (increase in size and weight) occurs the year after pollination.

In natural forests, conifers take several years before producing seed cones, but once production has begun, it usually increases with tree age and continues for the rest of the tree's life. Production is highly irregular in both space (among trees within a stand and among stands) and time (from year-to-year). The abundance of cones produced varies among species and is influenced by nutritional factors, environmental conditions, site characteristics and altitude. For most conifers, large seed crops are synchronized and episodic, a phenomenon referred to as masting. For most species, the intervals between

[1] Throughout this guide, words in bold font are defined in the glossary

mast years vary between 2-10 years and are interspersed by years of moderate, light or no cone crops. The distribution of seed cones usually varies among crown levels. Often, the upper crown, where light is more abundant, generally produces more cones than shaded areas. The greatest level of spatial heterogeneity within and between trees, as well as between stands, occurs on edges and during years of poor to moderate crops, when production is either limited to a few trees, or to few cones on several trees.

Insect diversity and community structure

Not all insects found in seed cones feed on, or destroy, seed cones or seeds. Seed cones are inhabited primarily by insect species that feed on plant tissues (i.e., **phytophages**). These insects create suitable conditions for the development of other groups of insects such as those that feed on decaying matter (e.g., **saprophages**) and on fungi (e.g., **mycophages**). In addition, feeding galleries created by phytophagous insects occasionally serve as hibernating sites for other groups of insects. Associated with all these insects are parasitoids and predators. Detailed knowledge of the entire insect community is limited to a handful of conifer species. There is a paucity of information on the natural enemies that attack insects infesting seeds and cones predominantly because the cryptic nature of these insects makes it difficult to ascertain the associations between insects and parasitoids.

There are approximately 400 species of phytophagous insects infesting the seed cones of world conifers; in eastern Canada, about 60 species of insects have been recorded on the native species of balsam fir, eastern larch, black, red and white spruce, jack, red, pitch, and white pine, and eastern hemlock (Table 1). All 60 species appear native to North America. This fauna comprises Coleoptera (e.g., cone beetles), Diptera (e.g., cone maggots, cone midges, resin midges, etc), Hemiptera (e.g., seed bugs, aphids, etc,), Hymenoptera (e.g., seed chalcids) and Lepidoptera (e.g., cone moths, cone borers, seed moths, coneworms, etc,). Note that several of these genera (i.e., *Strobilomyia*, *Megastigmus*, *Eucosma*, *Cydia*, etc,) are found in cones of conifers from around the world, only the species name is different. Most of the insect species found in cones of northeastern North America conifers are moths (Table 1).

Based on available host records, the diversity of most species of conifers from northeastern North America is limited to 12 species of phytophages or less (Table 1). Only eastern larch, black and white spruce appear to have a more diverse insect fauna. There is little doubt that many more host records remain to be established as detailed studies are lacking for several species of conifers, especially for those of little economic importance.

Associations: Insects can affect the survival of seeds directly by feeding on seed-cones, or indirectly by damaging foliage, twigs and branches that bear reproductive structures. Only a few of the 60 species found in northeastern North America can cause significant economic damage: the remainder typically have a low or unknown impact (Table 1). Some of the insects that have a direct impact on seed-cones feed exclusively on reproductive structures and cannot develop without them. These insects are known in the scientific literature as **conophytes**, but in this guide, we will refer to these insects as obligatory.

Other insects, which are not dependent on these structures for survival but will feed upon them opportunistically, are known as **heteroconophytes** but will be referred to as facultative. For the majority of northeastern conifers, most insects found in seed cones are obligatory: about 80% or higher (Table 1). Again the only exceptions are eastern larch and black spruce where the proportion of obligatory species is around 50%. The much lower proportion of obligatory species in these hosts can be attributed in part to detailed life table studies that revealed the presence of many facultative insects feeding on seed cones in the early stages of cone development. Nonetheless the focus of this guide will remain on obligatory species. Note that species from the same genus typically have the same type of associations (i.e., obligatory or facultative).

Feeding patterns: Four patterns of feeding upon seed cone tissues have been recognised for phytophagous insects. In the scientific literature they are referred to as conophagous, conospermatophagous, spermatophagous, and ecto-spermatophagous; however, for the purpose of brevity and simplicity, these feeding patterns will be referred to as Pattern I, II, III, and IV, respectively. Pattern I consists of feeding upon either cone axis, bracts or scales without specifically targeting seeds, although on occasion, tunnelling by larvae may result in some seeds being damaged or destroyed accidentally (Figure 2; Pattern I). Pattern II involves the consumption of cone and seed tissues by insects that move from seed to seed in a clear, discriminate pattern (Figure 2; Pattern II). Pattern III consists of feeding upon the endosperm from within seeds (Figure 2; Pattern III), whereas Pattern IV involves the consumption of endosperm, either partially or completely, by inserting piercing mouthparts from the cone's surface (Figure 2; Pattern IV). Patterns I-III are made by larvae whereas Pattern IV is caused by nymphs and adults alike.

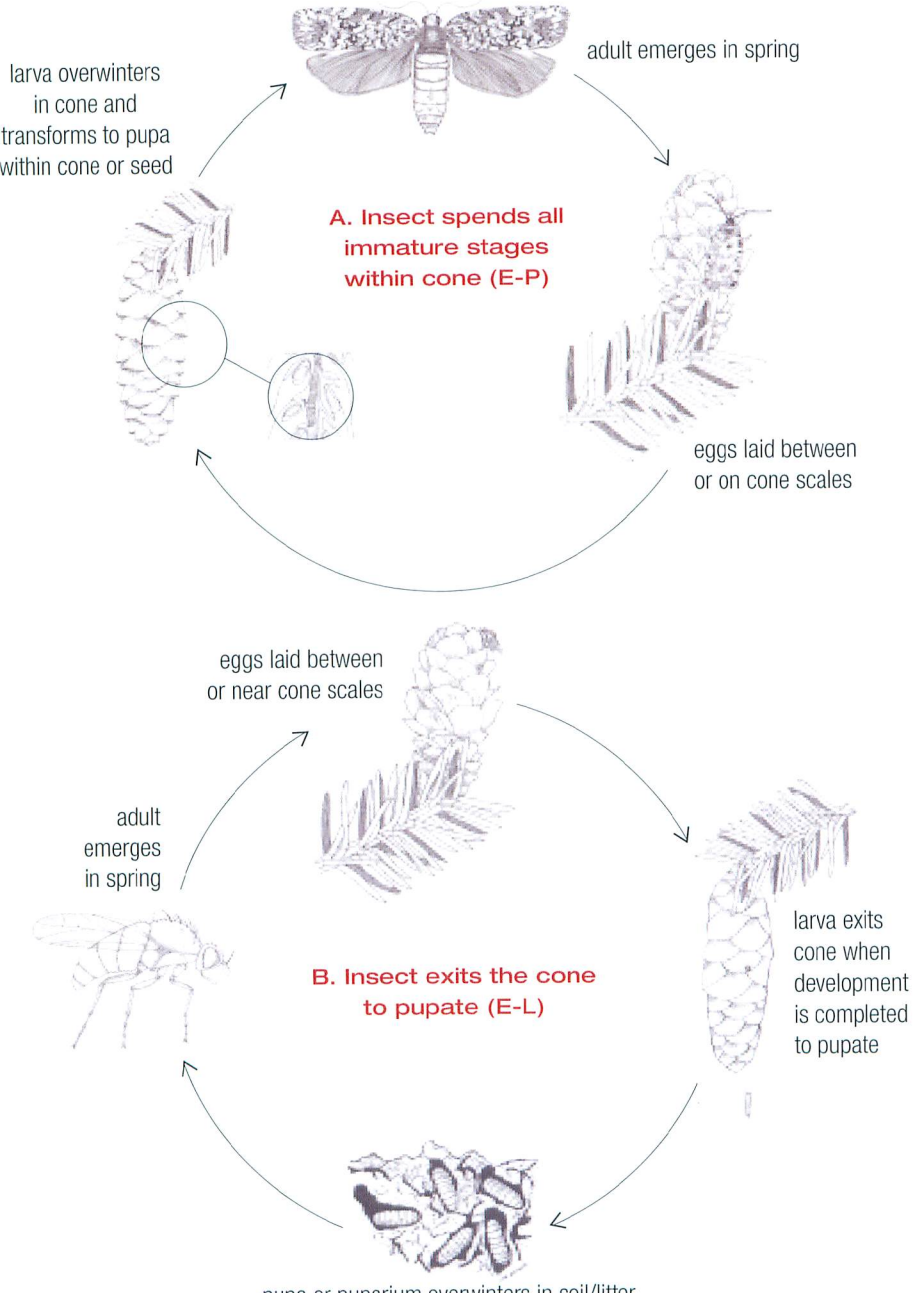
The feeding patterns of most insects found in seed cones of conifers from northeastern North America have been determined (Table 1). Facultative insects typically feed by grazing upon the outside of cone scales (i.e., Pattern I). This surface feeding, often characterised by the presence of coarse frass pellets, is usually easy to detect by a visual examination of the cone's surface, but is often difficult to associate to a specific feeder because of its nondiscriminatory nature. Species such as the spruce budworm, however, can either tunnel through the cone at random, damaging seeds by accident or consume the cone entirely especially when populations reach outbreak conditions and current-year foliage is scarce. Obligatory insects, on the other hand, have developed feeding strategies that target exclusively specific tissues of the cones and thus are considered much more specialised than facultative insects. One of the benefits of this specialisation is that it maximises the utilisation of the cone and reduces competition for resources by the species infesting the same cone, a strategy that would ensure survival of many insects species, especially when cones are scarce. All four feeding patterns are encountered among obligatory species. Obligatory species belonging to the same genus have similiar feeding patterns. For example, all species of *Conophthorus*, *Strobilomyia* and *Megastigmus* share Pattern I, II and III, respectively. It appears this pattern applies to the entire community of world conifer seed cones irrespective of the host exploited. For most conifer species, there are typically more species feeding on cone tissues (Pattern I) than on cone and seed tissues (Pattern II). Feeding on seed tissues (Pattern III and IV) is limited to a few species

only (Table I). Eggs of most obligatory species are laid between the cone scales, the bud scales or seeds. Thus, detection of most species is difficult because their eggs are small and the larvae develop inside cones and seeds (which offer protection) leaving little or no evidence of their presence. Consequently, detection occurs after damage has either started or has been completed; one exception are cone beetles.

Grazing by most facultative defoliators and needle miners (Pattern I) generally has a minimal impact on seed cone survival; however, extenstive surface feeding can result in mis-shaped or twisted cones and reduce seed extractability significantly. When taken individually, most facultative species have a low impact on the seed crop; however, when taken as a group the impact can be important, especially during outbreaks. For obligatory species, the impact associated with each feeding pattern varies substantially within and among patterns: from light, where extraction of a few seeds is prevented, to complete destruction, where the cone is killed prior to maturation. For example, some cone gall midge larvae form a small gall on cone scales near the axis (Pattern I), and can prevent extraction of 1 or 2 healthy seeds if the gall is located near the seeds of the infested scale. Pine cone beetle larvae, on the other hand, feed at random within cones (Pattern I), but all seeds are destroyed because the stem has been girdled by the female at the time of attack. Infestations by insects that mine the cones (Pattern II) do not necessarily result in the loss of all the viable seeds; thus the impact is likely function of the number of individuals in a cone and the seed-destroying capacity of each larva. A single spruce cone maggot can destroy an average of 65% of the seeds within a white spruce cone and about 75% of those from a black spruce cone. The filled seeds remaining in these cones are smaller than normal seeds but can germinate successfully; however, there is a significant reduction in extractability. Larvae of seed chalcids and seed midges (Pattern III) each consume one seed during their development. Thus the impact of this type of feeding is equivalent to the proportion of seed infested. Estimates of impact for the western conifer seed bug (Pattern IV) varies substantially among host species: Douglas fir (<5-70%), western white pine (70-80%), ponderosa pine (<55%), on whitebark pine (<2.1%) and lodgepole pine (<95%).

Life cycles: Almost all obligatory insects from northeastern North America have a **univoltine** life cycle. There is, however, a subtle variation in life cycle among the obligatory species that is noteworthy. Some species spend all immature stages of development (i.e., egg, larva and pupa) within the cone or seed (Figure 3a) whereas others exit the cone as a mature larva and pupate either in the litter or in the ground (Figure 3b). These types of life cycles, known in the literature as **endoconophytic** and **exoconophytic**, respectively, will be referred to as egg to pupa (hereafter E-P) or egg to larva (hereafter E-L) cycles. The type of life cycle is known for all obligatory species (Table 1). Obligatory species belonging to the same genus usually have similiar types of life cycles irrespective of the host infested. For example, all *Cydia* spp. have an E-P cycle whereas all *Strobilomyia* and *Eucosma* spp. have an E-L cycle. Notable exceptions are *Conophthorus resinosae*, which overwinters in shoots whereas *Conophthorus coniperda* remains in cones, and *Dioryctria* spp., which either remain in cones or leave cones to pupate.

Figure 3.
TYPES OF LIFE CYCLES FOR INSECTS INFESTING SEED CONES



Species with an E-P cycle overwinter as **diapausing** larvae or pupae within the brood cone or seed still attached to the tree or on the ground. Conversely, species with an E-L cycle overwinter in the duff beneath the tree or on the tree, either as diapausing pupae (e.g., *Strobilomyia* spp.) or mature larvae (e.g., *Dioryctria* spp.), but also as adults (e.g., *Conophthorus* spp.). Facultative insects rarely complete their life cycle within a cone as they move to foliage once it is available.

There appears to be relationships between the type of feeding pattern, the level of host specificity, the host plant and the type of life cycle. For example, all species with feeding Pattern III have an E-P life cycle; about 60% of the monophagous feeders have an E-P cycle compared to only 25% for oligophagous species; the number of species with an E-L cycle infesting balsam fir, eastern larch and pines is much greater than that with an E-P cycle whereas on spruces the opposite is observed.

Host specificity: Most obligatory species are moderately host specific, as indicated by the small number of hosts exploited (Table 1). Overall, about 70% of the obligatory species from northeastern North America with known host records are monophagous (i.e., feeding is apparently restricted to species from a single genus of Pinaceae); the remainder are oligophagous (i.e., feeding is apparently restricted to two or more genera of Pinaceae). On most conifer species, there is similiar proportion of monophagous and oligophagous species.

The degree of host specialization varies among feeding patterns. The proportion of monophagous species is much higher among obligatory species with a feeding Pattern II (12 out of 14) or III (5 out of 7) than among those with a Pattern I (6 out of 13). These patterns suggest a unique and specialized fauna.

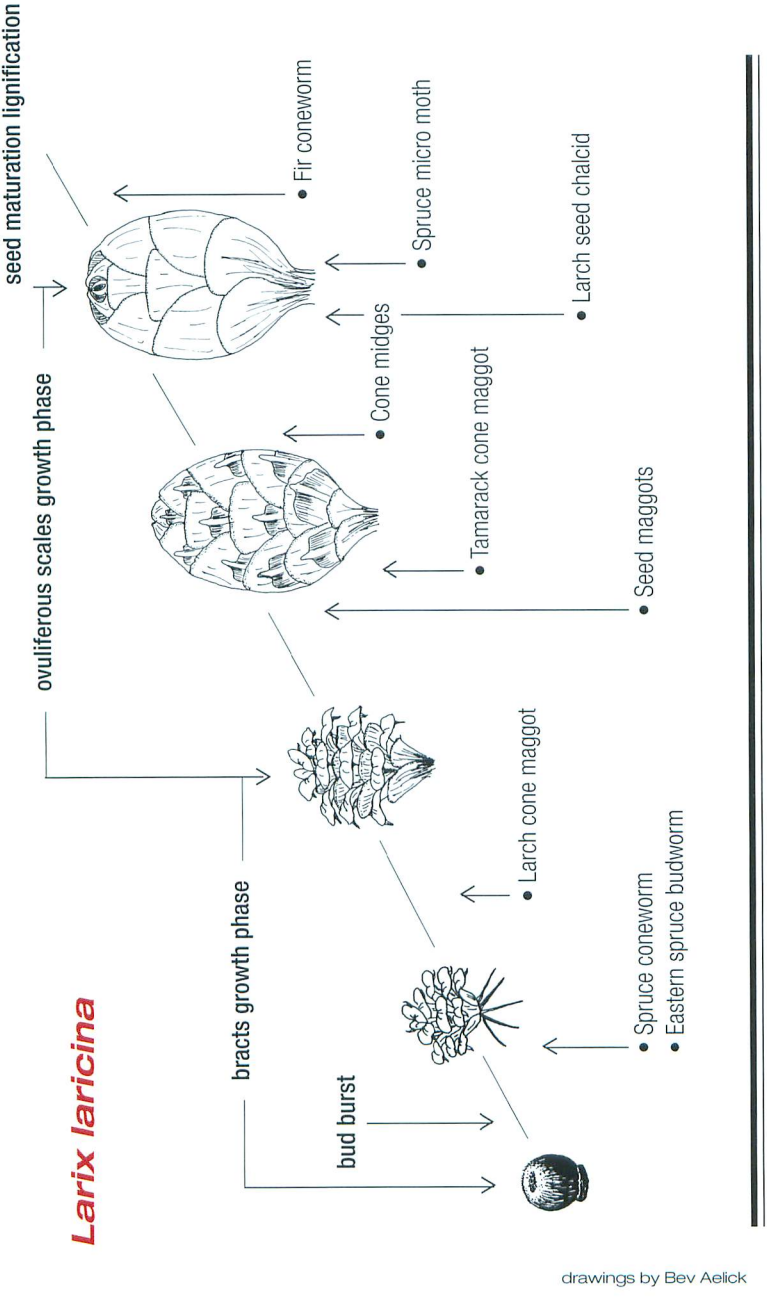
Insect-seed cone relationships

Fluctuations in the production of seed cones by the host tree is the single most important regulating mechanism in the population dynamics of most obligatory species. Besides evolving feeding strategies, cone feeders also had to develop strategies to adjust to the temporal availability of seed cones within seasons to enable synchrony of attack with seed cone development, and between seasons to ensure availability of cones.

Adjustments within a season: In northeastern North America, the relationship between seed cone **phenology** and the time of colonization by obligatory and facultative species have been established for some species (e.g., *Larix*, *Picea*, and *Pinus*; Figures 4,5 and 6). Facultative insects do not lay eggs on or near the cones. The larvae usually initiate cone attack when seed-cones begin to burst open or at the time cones are about to release seeds, when cone and foliage tissues are relatively similiar in composition. Conversely, most obligatory insects initiate cone attack by laying eggs between cone or bud scales when the seed-cones are open to receive pollen, with only a few species (e.g., seed chalcids) laying eggs in seeds when the cones are about half their mature length. At that time, cones are soft and contain high levels of sugars and low proportions of indigestible fibres. Obligatory species typically remain in cones until **lignification** is complete or seeds

Figure 4.

RELATIONSHIP BETWEEN THE TIME INSECTS INITIATE CONE ATTACK AND CONE PHENOLOGY OF EASTERN LARCH



drawings by Bev Aelick

are released, except for *Strobilomyia* spp. which exit cones shortly after the rapid growth phase is completed. The exit period generally lasts much longer than the **oviposition** period, and can be influenced by external cues such as rainfall. The mechanism enabling insects to synchronize colonization with specific phases of seed cone development is poorly understood.

Adjustments among seasons: As indicated above, the intervals between **mast** years, which varies among conifer species, are interspersed by several years of moderate, light or no cone crops. Insects have developed several adaptations to cope with these, sometimes drastic, annual variations in seed cone abundance. These adaptations seem designed mainly to assure survival of some individuals and to prevent extinction in the absence of cones rather than to maintain current population levels, or to permit populations to recover quickly.

Some species offset annual fluctuations by attacking seed cones from a wide variety of hosts (e.g., *Dioryctria abietivorella*); others infest different tree structures of different hosts (e.g., *Conophthorus resinosae*). Dispersal flights to locate cone producing stands have also been reported. Also, some obligatory species adjust oviposition by increasing, or decreasing the number of eggs laid per attacked cone when the cone crop decreases or increases. The most common strategy adopted by obligatory species infesting conifers with two year cycles (e.g., balsam fir, eastern larch) is prolonged **diapause**, where insects remain in diapause for more than a year. Of the 36 obligatory species infesting the seed cones of northeastern North American conifers, at least 23 are capable of prolonged diapause for a minimum of 1 to 3 additional years. Several parasitoids of these species are also capable of a prolonged diapause that is well synchronized with that of the host.

Typically, prolonged diapause occurs at the overwintering site (e.g., cone, duff, or seed in duff) and begins when insects reach the overwintering stage: either late instars (e.g., species of *Megastigmus* and *Cydia*) or pupae (e.g., species of *Strobilomyia* and *Earomyia*). The capacity to extend diapause is higher among obligatory species infesting conifers with two year cycles than among those with three year cycles. For example, between 60 and 85% of the species infesting seed cones of balsam fir, eastern larch and spruces are capable of prolonged diapause compared to less than 30% for those infesting pines (Table 1).

There is evidence to suggest that the incidence and duration of prolonged diapause varies among insects of the same species occupying the same cone, different cones on the same tree, different trees in the same stand and different sites, but appears independent of densities in seed cones. The communities of obligatory species are composed of individuals originating from different years. For most species, there is a negative relationship between the incidence of prolonged diapause and the size of the cone crop the year following larval feeding (i.e., an increase in cone production the following year should result in lower incidence of prolonged diapause).

drawings by Bev Aelick

Figure 5.
RELATIONSHIP BETWEEN THE TIME INSECTS INITIATE CONE ATTACK AND CONE PHENOLOGY OF SPRUCE

Except for two species of *Eucosma* (feeding Pattern II), which infest pine cones, all obligatory species with a feeding Pattern II or III have the capability to extend diapause. Only 35% of the obligatory species with a feeding Pattern I can extend diapause.

The factors regulating the induction and termination of prolonged diapause are poorly understood. **Abiotic** factors such as temperature, rainfall, and solar radiation as well as biotic factors such as host and maternal effect can play a primary role in diapause initiation of some obligatory species. The role of biotic factors on induction of prolonged diapause, however, appears limited to obligatory species that exploit seed cones at the time seed cone bud initiation occurs. Also, it has been suggested that the chemical composition of seed cones during larval development has an effect on the prolonged diapause of some species. For some obligatory species in prolonged diapause, termination was sometimes positively correlated with the cone production of host trees, whereas for others no relationship could be established. Prolonged diapause is probably terminated by the action of abiotic factors because diapausing individuals are either in the litter or in a cone or a seed in the duff. Temperatures occurring at specific periods in the spring preceding emergence seemed effective in predicting the proportion of some species that terminated prolonged diapause. Alternatively, termination of diapause or prolonged diapause could be genetically programmed. Females could produce a progeny with a mixture of diapause lengths with various proportions of a female's progeny ending diapause in any given year.

Host selection

For facultative species such as *Choristoneura* spp., seed cones are selected by larvae capable of significant movements to find cones. For obligatory species, adult females are responsible for seed cone recognition and selection and the progeny is bound to the female's choice except for a few species of *Eucosma* and *Eupithecia* whose larvae often move to another cone to complete development. Furthermore, most obligatory species mate either on cones, or in the vicinity of cones or cone producing trees, suggesting that cones probably act as "rendez vous" sites for both sexes. Thus, for these obligatory insects, effective host recognition and selection processes are required by adults to adjust to variations in the spatial distribution of seed cones.

For insects of seed cones, the plant selection process can be arbitrarily divided into three elements: detection of cone producing trees from a distance, from nearby, and detection of seed cones from within the tree canopy. There is increasing evidence suggesting that several obligatory species rely on a combination of visual (e.g., tree silhouette, size, shape, as well as cone size, shape, colour and contrast with foliage) and olfactory (e.g., scent emitted by trees or cones) cues, operating sequentially or simultaneously, in locating cone producing trees or seed cones.

Traps mimicking these stimuli can be hung in front of trees or within the canopy and used to attract adults, thus serving as monitoring tools. The response of insects to visual cues provided by trees or cones may vary among sexes and can be influenced by the reproductive and nutritional status of the individual insect.

Figures 6.
RELATIONSHIP BETWEEN THE TIME INSECTS INITIATE CONE ATTACK AND CONE PHENOLOGY OF PINE

drawings by Bev Aelick

INDENTIFYING INSECTS INFESTING SEED CONES

Introduction

The ability to identify the species of insects attacking the cones and seeds of conifers is critically important for pest management. This is because pest control methods are developed, tested, and approved for certain species or groups of insects. In other words, what works for one species is not necessarily effective against another one. Thus, failure to correctly identify the insects can result in ineffective and costly pest management and possibly in illegal use of registered insecticides. Furthermore, to prevent seed losses it is critical that insect identification be performed in a timely manner so that appropriate damage assessment be initiated as soon as possible.

Insect identification, a process that may on occasion take several weeks (from shipping the insect to actual identification), is based on certain unique morphological, behavioural, chemical or other traits and is performed by taxonomists. For those working in the field, these traits are often difficult or impossible to see with the naked eye and require special equipment and training available only to taxonomists. Fortunately, most insects have specific feeding habits and thus leave a characteristic signs of damage that we believe are much easier to see and recognise by those working in the field. Furthermore, most insects feed preferentially on a specific host genus (i.e., spruce, pine, etc.): only a handful feed on several host genera. A list of each insect and feeding characteristics was compiled for each host genus, and, when possible, associated with a photograph that best illustrated the damage one would see. With this information, an easy-to-use key was developed to aid in the identification of insects attacking the cones and seed of balsam fir, eastern larch, spruce, pine and eastern hemlock, in eastern Canada.

The first step is to determine whether there is evidence of insect damage on the cones surface:

1 There is external evidence of damage.....List of possible insects
1' There is NO external evidence of damage.....Proceed to step 2

The second step consists of slicing the cone in half lengthwise, along the axis, and determining whether there is evidence of damage to the seeds:

2 Damage to seed is visible.....List of possible insects
2' Damage to seed is NOT visible.....List of possible insects

For insects leaving external evidence of damage, the external damage is described first, and is followed by a description of internal damage which can be observed once the cone is bisected. NEVER ASSUME THAT BECAUSE A CONE LOOKS HEALTHY FROM THE OUTSIDE THAT IT CONTAINS HEALTHY VIABLE SEEDS INSIDE. Thus, we urge you to take the time to bisect healthy cones as well. Insects leaving no external evidence of damage have been divided into two groups based on the presence or absence of visible damage to the seeds, once the cone is bisected. After matching the damage you observe to a photograph or a description,

read the name of the insect or insects, and the page number (in brackets) where you will find additional information on the insect.

This method of identification is not fool-proof and doesn't work for every cone and seed insect, but it does work in the vast majority of cases.

INSECTS DAMAGING BALSAM FIR CONES

INSECTS LEAVING EXTERNAL EVIDENCE OF DAMAGE

T Arcand

• conspicuous reddish-brown, coarse frass and webbing holding several cones together; one or more ragged holes; extensive tunnelling inside cone, usually free of debris.
fir coneworm (89)
(Dioryctria abietivorella)

T Arcand

• small ragged holes on cone surface; small amounts of frass and resinous material around entrance holes.
spruce cone loopers (99)
(Eupithecia albicapitata)
(Eupithecia mutata)

Canadian Forest Service

• cone exterior partially consumed; webbing and coarse frass adhering to surface of cone and surrounding needles.
eastern spruce budworm (81)
(Choristoneura fumiferana)

INSECTS DAMAGING BALSAM FIR CONES

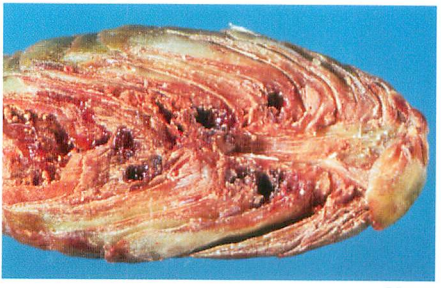
INSECTS LEAVING NO EXTERNAL EVIDENCE OF DAMAGE

Oregon State University

Damage to seeds is visible

- small amount of frass present; attacked seeds become flat, resinous, and dark brown.

seed maggots (45)
(Earomyia atterima)



E Rayner

- spiral tunnel around cone axis filled with resin and frass; seeds can be partially or totally consumed; small amounts of brown boring and fecal debris.

balsam fir cone maggot[1]
(Strobilomyia carbonaria)

D Ruth

Damage to seeds is not visible

- seeds appear normal; endosperm consumed entirely by insect.

balsam fir seed chalcid (77)
(Megastigmus specularis)

balsam fir

[1] There is insufficient information to prepare a fact sheet, but this insect's appearance resembles that of a spruce cone maggot (except in size). Damage by spruce cone maggot shown here.

INSECTS DAMAGING EASTERN LARCH CONES

INSECTS LEAVING EXTERNAL EVIDENCE OF DAMAGE

T Arcand

• cone enveloped in coarse frass and webbing in early June.
spruce coneworm (93)
(Dioryctria reniculelloides)
(shown on black spruce)

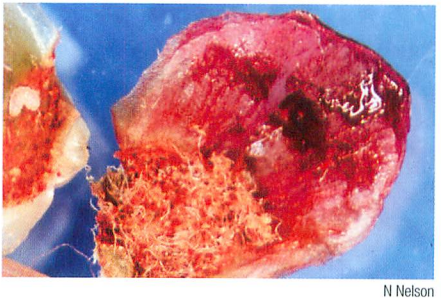
Canadian Forest Service

• cone partially consumed; webbing and frass adhering to surface.
eastern spruce budworm (81)
(Choristoneura fumiferana)

N Nelson

• conspicuous, coarse frass and webbing around tip of cone in late June; extensive tunnelling inside cone.
fir coneworm (89)
(Dioryctria abietivorella)

INSECTS LEAVING NO EXTERNAL EVIDENCE OF DAMAGE



N Nelson

Damage to seeds is visible
• spiral tunnelling around cone axis; all seeds totally consumed; large amounts of filamentous and granular frass.
larch cone maggot (57)
(Strobilomyia laricis)

N Nelson

• spiral tunnelling around cone axis; seeds partially to totally consumed; small amount of filamentous frass.
tamarack cone maggot (61)
(Strobilomyia viaria)

N Nelson

• resin can occur between scales; no tunnelling or debris is present; damaged seeds are brown.
cone midges (53)
(Resseliella spp.*)*

Oregon State University

• small amount of frass present; attacked seeds become flat, resinous, and dark brown.
seed maggots (45)
(Earomyia spp.*)*
(shown on balsam fir)

eastern larch

INSECTS DAMAGING EASTERN LARCH CONES

INSECTS LEAVING NO EXTERNAL EVIDENCE OF DAMAGE

T Arcand

• tunnel around the axis; small granular frass present.
spruce micro moth[1]
(Endopiza piceana)

Canadian Forest Service

Damage to seeds is not visible
• seeds appear normal; endosperm consumed entirely by insect.
larch seed chalcid (75)
(Megastigmus laricis)

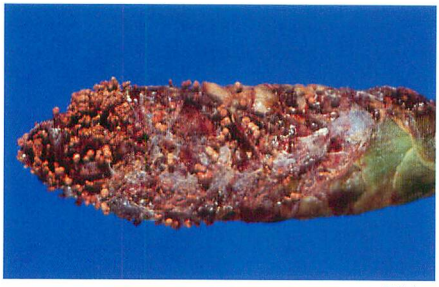
eastern larch

[1] There is insufficient information to prepare a fact sheet.

INSECTS LEAVING EXTERNAL EVIDENCE OF DAMAGE

T Arcand

• ragged holes on cone surface; small amounts of frass and resinous material around entrance holes.
spruce cone loopers (99)
(Eupithecia albicapitata)
(Eupithecia mutata)
(shown on balsam fir)



N Nelson

• small entrance hole in lower half of cone surface; granular, fine, reddish-brown frass trapped in webbing on outside of cone below the hole.
spruce micro moth[1]
(Endopiza piceana)

B Aelick

• from late June or early July, a small exit hole can be found on cone surface; infested cones usually smaller than healthy cones; spiral tunnel around cone axis filled with resin and frass; seeds and scales partially or totally consumed with small amounts of brown boring and fecal debris.
black spruce cone maggot (55)
(Strobilomyia appalachensis)
or
white spruce cone maggot (59)
(Strobilomyia neanthracina)

spruce

[1] There is insufficient information to prepare a fact sheet.

INSECTS DAMAGING SPRUCE CONES

INSECTS LEAVING EXTERNAL EVIDENCE OF DAMAGE

J Turgeon

• conspicuous reddish-brown, coarse frass and webbing holding several cones together; one or more ragged holes; extensive tunnelling inside cone, usually free of debris.
fir coneworm (89)
(Dioryctria abietivorella)

E Rayner

• cone exterior partially consumed; webbing and coarse frass adhering to surface of cone and surrounding needles.
eastern spruce budworm (81)
(Choristoneura fumiferana)

T Arcand

• infested cones and surrounding shoots enveloped in coarse frass and webbing; severely infested cones hollowed out.
spruce coneworm (93)
(Dioryctria reniculelloides)

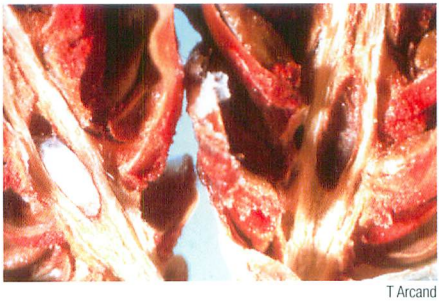
INSECTS LEAVING NO EXTERNAL EVIDENCE OF DAMAGE

D Ruth

Damage is visible, but not on seed

- small swelling or gall on the inner surface of cone scales or near the seed, which may prevent seed extraction.

spruce cone gall midge (47)
(Kaltenbachiola canadensis)



T Arcand

- small chamber in cone axis; seeds show no apparent damage.

spruce cone axis midge (49)
(Kaltenbachiola rachiphaga)

D Ruth

Damage to seeds is visible

- resin can occur between scales; no tunnelling or debris is present; damaged seeds are brown.

cone midges (53)
(Resseliella spp.*)*

E Rayner

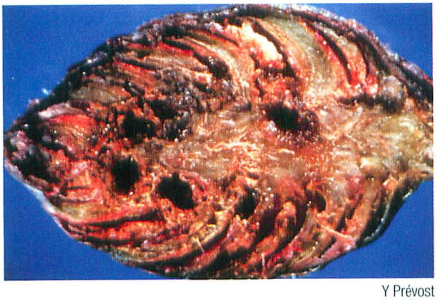
- silk in tunnels between seed pairs; small holes with fine frass on either side of cone slice; seeds partially to completely consumed and fused to scale.

spruce seed moth (85)
(Cydia strobilella)

spruce

INSECTS DAMAGING SPRUCE CONES

INSECTS LEAVING NO EXTERNAL EVIDENCE OF DAMAGE



Y Prévost

• spiral tunnel around cone axis filled with resin and frass; seeds can be partially or totally consumed; small amounts of brown boring and fecal debris.
black spruce cone maggot (55)
(Strobilomyia appalachensis)
white spruce cone maggot (59)
(Strobilomyia neanthracina)

D Ruth

• infested seeds are larger than normal seeds.
spruce seed midge (51)
(Mayetiola carpophaga)

Oregon State University

• attacked seeds are flat and dark brown; can contain resin.
seed maggots (45)
(Earomyia spp.*)*
(shown on balsam fir)

N Nelson

Damage to seeds is not visible
• seeds can be slightly enlarged but show no other form of damage; endosperm consumed entirely by insect.
spruce seed chalcid (71)
(Megastigmus atedius)

spruce

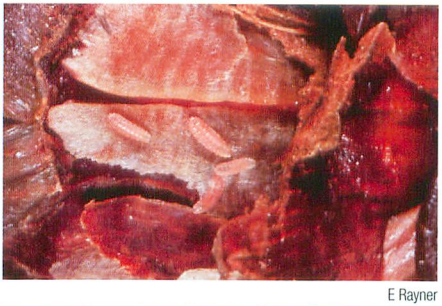
INSECTS LEAVING EXTERNAL EVIDENCE OF DAMAGE

J Turgeon

- distinctive yellow pitch tube, either on, or near, the cone petiole; pitch tube turns grey; cone becomes hard and dry with a shrivelled appearance.
white pine cone beetle (37)
(Conophthorus coniperda)

P de Groot

- transverse groove in cone base; resin accumulation mixed with fecal and boring debris at entrance hole; cone turns brown and hardens; interior of cone contains fine brown powder.
red pine cone beetle (39)
(Conophthorus resinosae)



E Rayner

- one to all cone scales shrivelled and brown; dry resin flakes may be present on cone exterior; fluid resin between attacked cone scales; no tunnelling or debris present; cones may be smaller than normal.
cone resin midge (43)
(Asynapta hopkinsi)

T Arcand

- one or more ragged holes; conspicuous, coarse frass and webbing around the entrance hole; extensive tunnelling inside the cone, usually free of debris.
fir coneworm (89)
(Dioryctria abietivorella)

INSECTS DAMAGING PINE CONES

INSECTS LEAVING EXTERNAL EVIDENCE OF DAMAGE

B Aelick

• single conspicuous hole near cone base with tightly webbed semi-coarse reddish-brown frass over the entrance hole; large excavation deep within seed-bearing region of cone containing dried resin, frass, and webbing.
webbing coneworm (91)
(Dioryctria disclusa)

T Arcand

• red pine cone with numerous small, round holes, or a few oblong holes in upper half on side of cone; exterior of cone almost always free of frass; no webbing found inside cone; cone interior packed with mixture of frass and resin; extensive tunnelling in cone.
red pine cone borer (95)
(Eucosma monitorana)

E Rayner

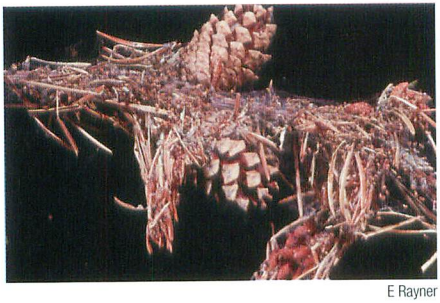
• white pine cone peppered with many small holes and covered with patches of extruding frass; cone interior is packed with a mixture of frass and resin; extensive tunnelling in cone.
white pine cone borer (97)
(Eucosma tocullionana)

INSECTS DAMAGING PINE CONES

INSECTS LEAVING EXTERNAL EVIDENCE OF DAMAGE

P de Groot

• one or more brown shrunken cone scales; resin can occur between scales; no funnelling or debris is present; damaged seeds are brown.
cone midges (53)
(Resseliella spp.*)*



E Rayner

• one or more holes may be present on cone surface; feeding on cone surface and surrounding needles with frass and webbing adhering to remaining needles; cone may be distorted due to destroyed conductive tissue.
jack pine budworm (83)
(Choristoneura pinus pinus)

INSECTS DAMAGING PINE CONES

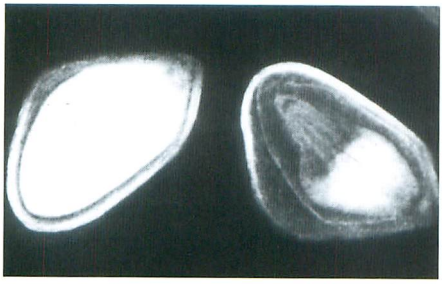
INSECTS LEAVING NO EXTERNAL EVIDENCE OF DAMAGE

P de Groot

Damage to seeds is visible

- tunnelling in cone axis; seed coat partially destroyed; remainder of seed coat glued to the scale, and filled with a mixture of frass and resin.

eastern pine seed moth (87)
(Cydia toreuta)



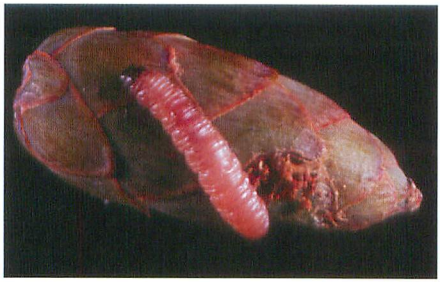
G DeBarr

Damage to seeds is not visible

- seed ovules damaged before seed coat hardening, are small or flattened; seeds damaged after seed coat hardening can only be detected by x-rays and are totally or partially empty.

shield-backed pine seed bug (67)
(Tetyra bipunctata)
or
western conifer seed bug (65)
(Leptoglossus occidentalis)

INSECTS LEAVING EXTERNAL EVIDENCE OF DAMAGE

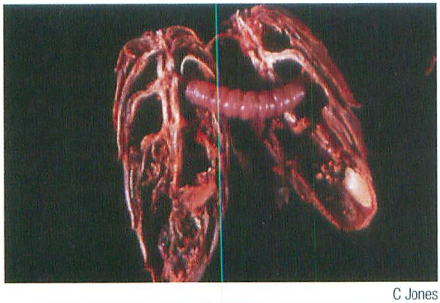


C Jones

• ragged holes on cone surface; small amounts of frass and resinous material around entrance holes; spiral tunnel around cone axis with seeds and scales partially or totally consumed and fused to scale with small amounts of brown boring and fecal debris.
spruce cone looper (99)
(Eupithecia mutata)

INSECTS DAMAGING EASTERN HEMLOCK CONES

INSECTS LEAVING NO EXTERNAL EVIDENCE OF DAMAGE



C Jones

Damage to seeds is visible

- seeds partially to completely consumed and fused to scale with small amounts of brown boring and fecal debris.

spruce cone looper (99)
(Eupithecia mutata)

C Jones

Damage to seeds is not visible

- seeds appear normal; endosperm consumed entirely by insect.

hemlock seed chalcid (73)
(Megastigmus hoffmeyeri)

FACT SHEETS ON INSECT PESTS

Introduction

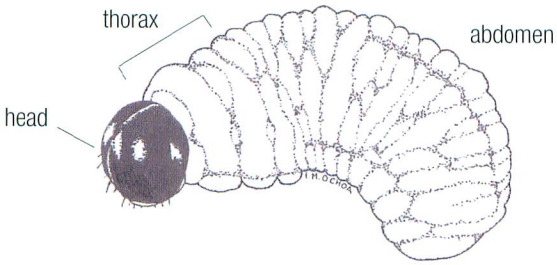
A fact sheet has been prepared for most obligatory, but only for a few of the major facultative, insects found in northeastern Canada. The information available on a few rare obligatory (e.g., *Barbara mappana, Strobilomyia carbonaria,* etc.,) and several frequently encountered, but minor, facultative insects (e.g., *Endopiza piceana, Holcocerina immaculella, Hapleginella conicola,* etc.,) is currently insufficient to prepare individual fact sheets.

Each fact sheet provides a synthesis of the taxonomic information necessary to perform more detailed literature searches on a specific insect. In addition, the most useful morphological characteristics that should enable the user to recognise and identify each insect at any stage of development, is presented in point form. If the morphological description does not match that of the insect found in the cone, yet matches the description of damage, you likely have the wrong insect species. Also included is a list of hosts (listed alphabetically, rather than preferentially) as well as a synopsis of the information available on distribution, type of damage it causes, importance, best way to sample/detect the insect, and management options available. The fact sheets have been arranged by insect order (e.g., Coleoptera, Diptera, etc.,) and alphabetically using the scientific name of the insect's genus. The fact sheets from each insect order are preceded by generic diagrams depicting the morphological features of the immature and mature stages of development.

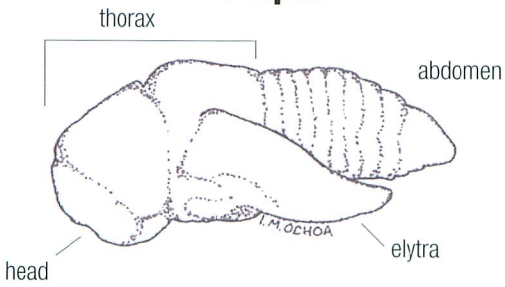
The life cycle of each insect has been presented graphically. The presence of each stage of development, as indicated by the bar, is not specific to any particular region of eastern Canada and thus should be viewed as a generic representation rather than an accurate depiction of the actual period of occurrence in the field. Life cycles are also dependent on weather and thus vary from year to year.

COLEOPTERA

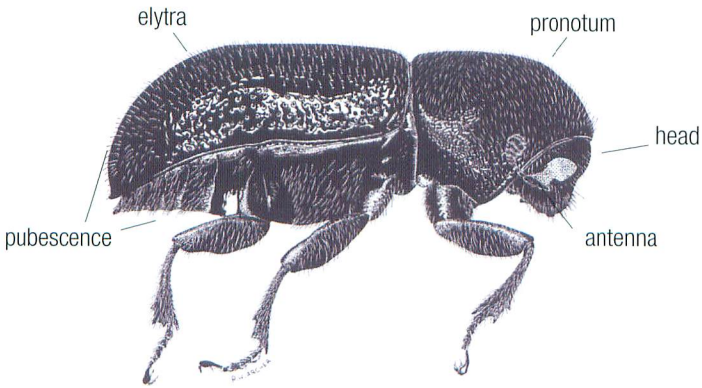
Larva



Pupa

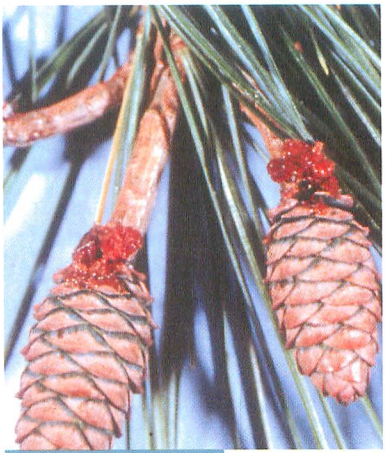


Adult



WHITE PINE CONE BEETLE

Adult E Rayner



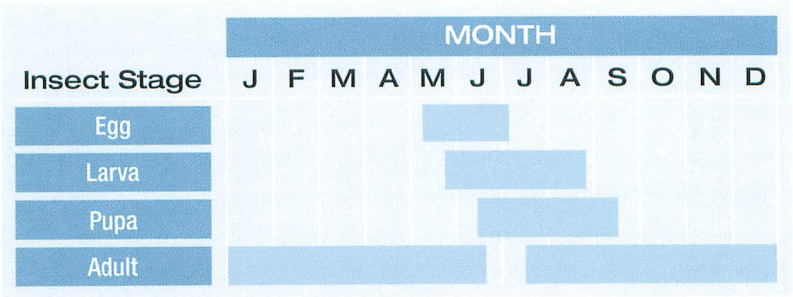
Entrance hole J Turgeon

TAXONOMY

Order (Family): Coleoptera (Scolytidae)
Scientific name: *Conophthorus coniperda* (Schwarz)
Synonym(s):
French name: Scolyte des cônes du pin blanc

INSECT DESCRIPTION

Egg: pearl white; 0.7-0.8 by 0.5 mm; ovoid; laid in galleries cut along centre of cone
Larva: two instars; creamy white with light brown head; 1.0-3.0 mm long; curved; legless; develops in dead cone
Pupa: white when first formed; after 4 or 5 days, the mouth parts, eye areas, and the end of the elytra darken; develops in dead cone on the ground
Adult: shiny black; 2.4-3.0 mm long; stout; cylindrical-shaped; covered with erect hairs (i.e., **pubescence**); beetle usually overwinters in dead cone on ground



HOST: Pine (eastern white)

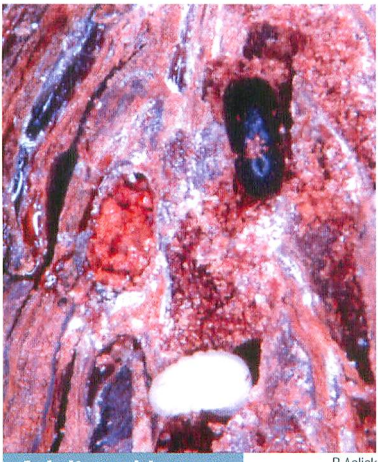
DISTRIBUTION: found throughout the range of eastern white pine
DAMAGE: entrance hole at cone and petiole junction surrounded by a distinctive yellow-brown pitch tube, which later turns greyish; conductive tissue severed near entrance hole causes seed development to cease; all seeds destroyed; cone becomes brown, shrivelled, and hard.
IMPORTANCE: up to 100% of a cone crop can be destroyed; seed mortality is 100% within each cone; one female can kill as many as 4 cones
DETECTION AND MONITORING: dissect cone to find all life stages; look for dead cones on ground after mid-July; barrier trap baited with sex **pheromone** is available

CONTROL
Silvicultural: raking and burning beetle-infested cones in the fall, or in the spring before beetle emergence, effectively reduces populations
Biological: none available
Chemical: soil application or stem implants of systemic insecticides have reduced populations; contact insecticides on small trees can be effective if foliage does not obstruct deposition of insecticide on the petiole and base of the cone

REFERENCES
Biology: Henson (1961,1966); Graber (1964); Odell and Godwin (1964); Godwin and Odell (1965); Morgan and Mailu (1976); Ebel *et al.* (1980); Hedlin *et al.* (1981); DeBarr *et al.* (1982); Brown and Amirault (1985); DeBarr (1989); Fogal and Plowman (1989); Valenti *et al.* (1990); de Groot *et al.* (1991, 1992, 1998); Birgersson *et al.* (1995); de Groot and DeBarr (1998, 2000); Rappaport *et al.* (2000)
Control: Morgan and Mailu (1976); DeBarr et al. (1982); Brown and Amirault (1985); Fogal and Plowman (1989); Valenti *et al.* (1990); Miller *et al.* (1995); Zylstra *et al.* (1995).

NOTES:

RED PINE CONE BEETLE



Adult and Larva B Aelick

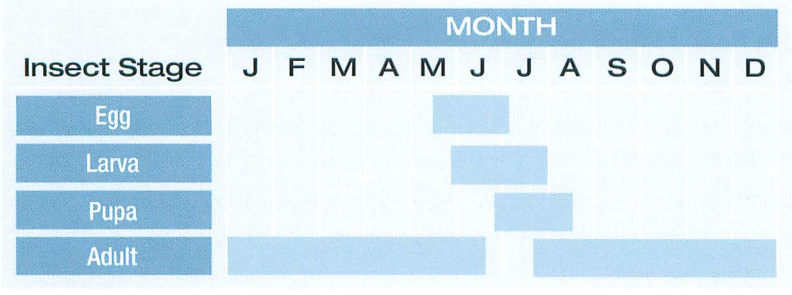
Damaged cone B Aelick

TAXONOMY

Order (Family): Coleoptera (Scolytidae)
Scientific name: *Conophthorus resinosae* Hopkins
Synonym(s): *Conophthorus banksianae* McPherson; *Conophthorus virginianae* Hopkins
French name: Scolyte des cônes du pin rouge

INSECT DESCRIPTION

Egg: pearl white; 0.9-1.0 by 0.5-0.8 mm; ovoid; laid in niches cut in gallery in centre of cone
Larva: two instars; creamy white with light brown head; 1.0-4.0 mm long; curved; soft-bodied and legless; develops in dead cone
Pupa: white when newly formed, darkening first on mandibles, eyes, and ends of elytra; 2.8-3.3 mm long; develops in dead cone on the tree
Adult: shiny black; 3.0-3.5 mm long; cylindrical-shaped beetle with sparse **pubescence**; overwinters in red pine shoot on forest floor



HOSTS: Pine (red, jack)

DISTRIBUTION: found throughout the range of red pine
DAMAGE: cone dry and shrivelled; transverse groove at base of cone; resin accumulation mixed with fecal and boring debris near entrance hole; cone contains fine, granular frass; young adult leaves the cone and bores into a branchlet, usually within 2 cm of bud tip; beetle-infested bud breaks off and drops to the ground, beginning in August
IMPORTANCE: between 60-100% of cones can be destroyed; 100% of seeds per cone are destroyed; one female can destroy up to 15 cones; rare on jack pine cones but common on jack pine shoots
DETECTION AND MONITORING: dissect cone to find all life stages; look for adults in buds on the ground after mid-September and before early May; barrier trap baited with sex **pheromone** is available

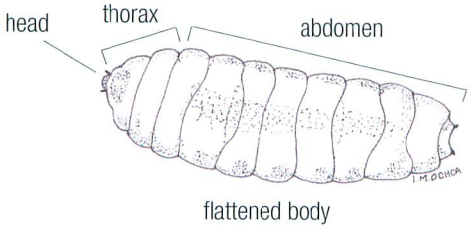
CONTROL
Silvicultural: raking and burning beetle-infested buds in the fall, or in the spring before beetle emergence, effectively reduces populations
Biological: none available
Chemical: soil application or stem implants of systemic insecticides have reduced populations; contact insecticides on small trees can be effective if foliage does not obstruct deposition of insecticide on the petiole and base of the cone

REFERENCES
Biology: Lyons (1956,1957c); Hard (1964); McPherson *et al.* (1970); Mattson (1971); Miller (1978); Hedlin *et al.* (1981); Brown and Amirault (1985); Rauf *et al.* (1985) de Groot (1986); de Groot (1991); de Groot and Borden (1991, 1992); de Groot *et al.* (1992, 2002); de Groot and Fleming (1994); de Groot and Zylstra (1995) Miller *et al.* (1995); Pierce *et al.* (1995); de Groot and MacDonald (1999); Rappaport *et al.* (2000)
Control: Miller (1978); Miller *et al.* (1995); Zylstra *et al.* (1995)

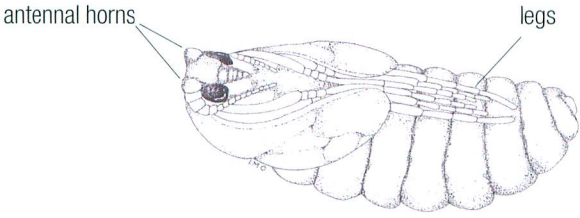
NOTES:

DIPTERA

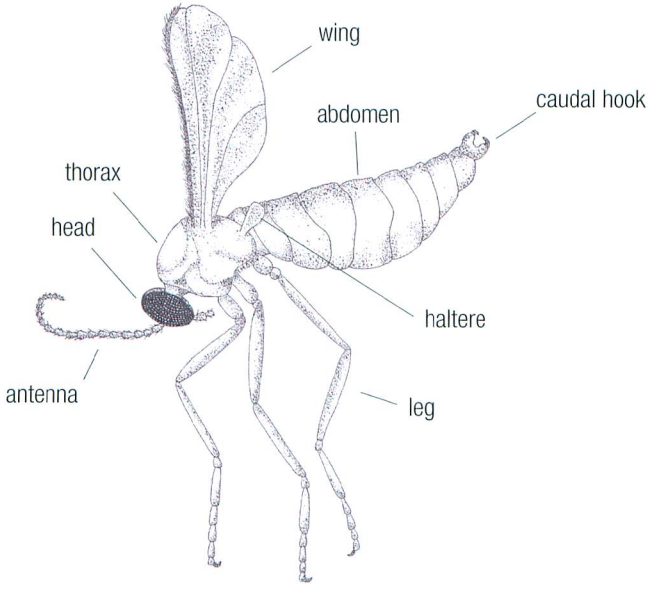
Larva



Pupa

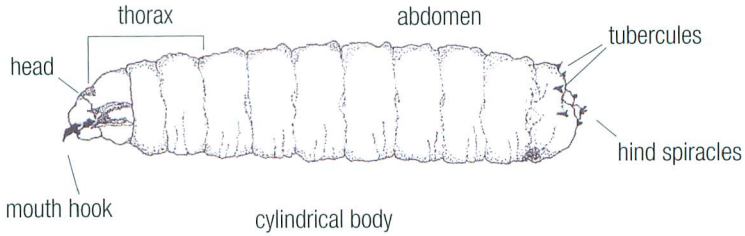


Adult

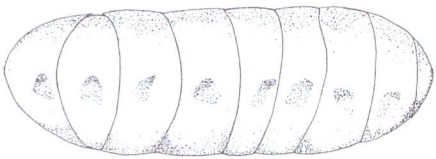


DIPTERA

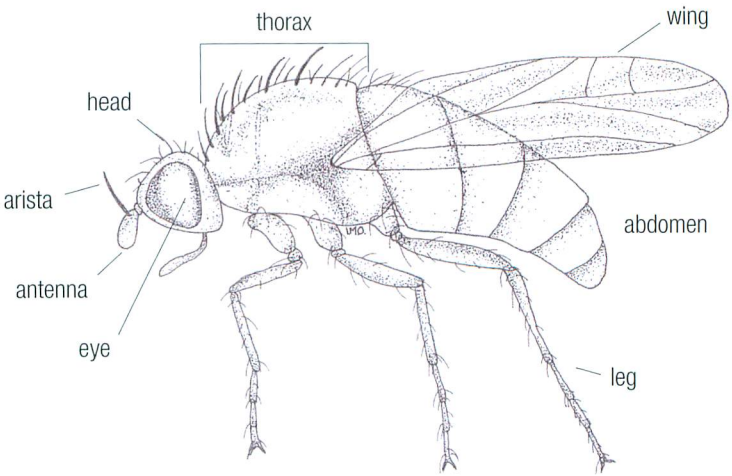
Larva



Puparium

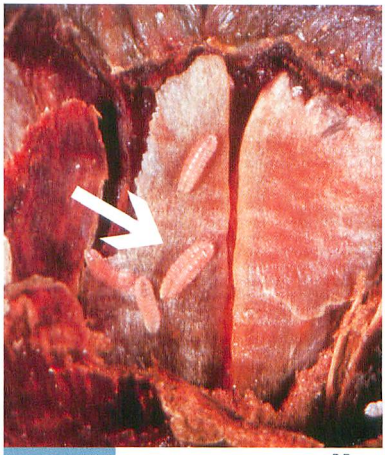


Adult



CONE RESIN MIDGE

Adult T Arcand



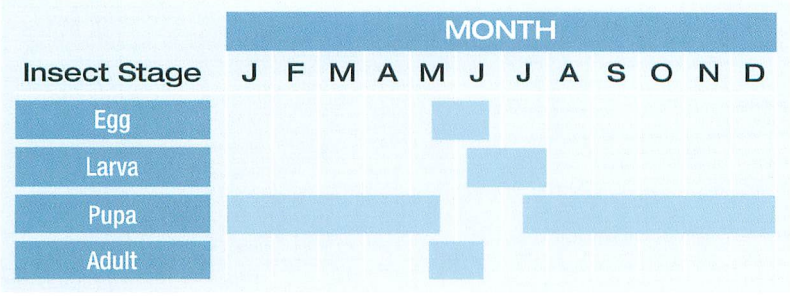
Larva E Rayner

TAXONOMY

Order (Family): Diptera (Cecidomyiidae)
Scientific name: *Asynapta hopkinsi* Felt
Synonym(s): *Asynapta keeni* (Foote); *Rubsaamenia* sp.
French name: Cécidomyie de la résine des cônes

INSECT DESCRIPTION

Egg: no description available
Larva: young midge almost colourless, 0.5 mm long; mature midge white, 2.0-3.0 mm long; slightly dorso-ventrally flattened with small **head capsule**; no **spatula** evident on underside; found in clusters between cone scales
Pupa: brown; **sclerotized**; found in a cocoon in cone or in the soil beneath tree
Adult: pink abdomen; clear wings; antennae are 2.0 mm



HOSTS: Pine (jack, red)

DISTRIBUTION: widely distributed
DAMAGE: distorted and brown cone scales; flakes of crystallized resin on exterior; notably free of any boring debris
IMPORTANCE: typically less than 10% of the cones are attacked; rarely more than 15% of the seeds per cone are lost
DETECTION AND MONITORING: dissect cone to find larvae; no **attractant** available

CONTROL
Silvicultural: none available
Biological: none available
Chemical: soil application of systemic insecticides has been effective in reducing populations

REFERENCES
Biology: Lyons (1957b,1957c); Hard (1964); Kulhavy *et al.* (1976); Ebel *et al.* (1980); Brown and Amirault (1985); Churcher *et al.* (1985); Rauf *et al.* (1985); de Groot (1986); Katovich and Kulman (1987a)
Control: Rush *et al.* (1987); Fogal and Plowman (1989)

NOTES:

SEED MAGGOTS

Egg

Canadian Forest Service

Larva

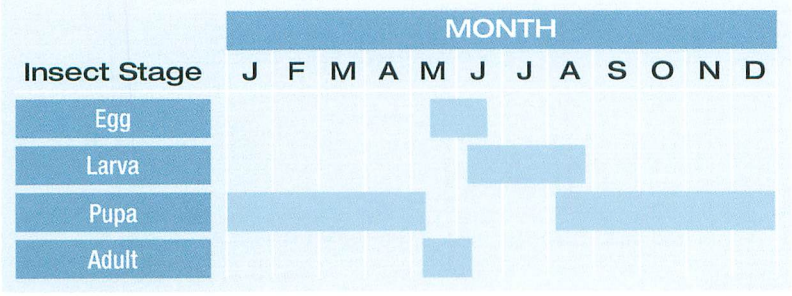
Canadian Forest Service

TAXONOMY

Order (Family): Diptera (Lonchaeidae)
Scientific name: *Earomyia* spp.
Synonym(s):
French name: Mouches conophages

INSECT DESCRIPTION

Egg: white; about 1.5 mm long; cylindrical; glossy; laid on inner surface of seed cone scales
Larva: creamy white; shiny; about 8.0 by 1.0 mm when mature, elongated with two distinct sharp black **mouth hooks** at head end; two prominent blunt projections (i.e., **spiracles**) on posterior; develops in seeds
Puparium: dark red-brown; 4.5-5.5 by 1.5mm; oblong with two prominent blunt projections on posterior; found in the cone or in duff beneath tree; capable of extended diapause
Adult: blue-black; shiny; **halteres** always black; wing length is about 4.0-5.0 mm



HOSTS: Fir (balsam); Larch (eastern); Spruce (white)

DISTRIBUTION: found throughout the range of fir and tamarack
DAMAGE: no external evidence of cone attack; larva tunnels around cone **axis** tunneling from seed to seed; attacked seeds are flat, limp and almost black; only a small amount of fine frass is produced
IMPORTANCE: typically less than 5% of the cone crop is damaged; a single larva destroys up to 25% of seeds
DETECTION AND MONITORING: dissect cone to find egg and larva; no **attractant** available

CONTROL
Silvicultural: remove infested cones from seed orchard in late summer and destroy before larvae drop
Biological: none available
Chemical: none available

REFERENCES
Biology: McAlpine (1956); Keen (1958); Kulhavy *et al.* (1976); Hedlin *et al.* (1981); McAlpine and Steyskal (1982); Brown and Amirault (1985);
Control: none available

NOTES:

SPRUCE CONE GALL MIDGE

Adult J Sweeney

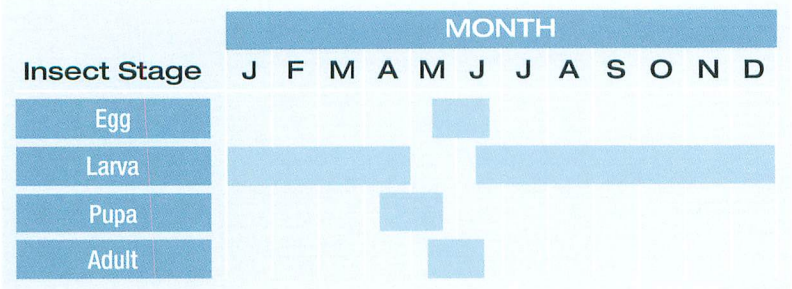
Larva T Arcand

TAXONOMY

Order (Family): Diptera (Cecidomyiidae)
Scientific name: *Kaltenbachiola canadensis* (Felt)
Synonym(s): *Dasineura canadensis* Felt
French name: Cécidomyie galligène des cônes de l'épinette

INSECT DESCRIPTION

Egg: whitish; 0.3 by 0.1 mm; oblong; smooth **chorion**; laid in groups of 2-3 on receptive cone scale during pollination
Larva: three instars; orange and about 3.0 mm long when mature; slightly dorso-ventrally flattened with small, faintly **sclerotized head capsule**; **spatula** present on underside near front end; head capsule no wider than spatula; without prominent lobes at hind end; antennae small; develops and overwinters in cone scales below seed wing or near seed; capable of extended diapause
Pupa: whitish in early stages, turning darker as it matures; about 2.5 mm long;



antennal horn stout, rounded with one sharp tooth; found in a white cocoon in the same cavity as larva
Adult: dark brown; about 2.2 mm long; mosquito-like

HOSTS: Spruce (black, red, white)

DISTRIBUTION: found throughout the range of spruce
DAMAGE: larva burrows through the seed wing or near the **axis** below the seed, forming a small gall; if the gall is adjacent to developing seeds, extraction can be difficult, otherwise the damage is minimal
IMPORTANCE: up to 90% of the cones can be infested; seed mortality is rare; individual trees can suffer heavier losses; if gall is adjacent to the seed(s), one larvae can prevent extraction of 1-2 healthy seeds
DETECTION AND MONITORING: dissect cone before it closes completely to find egg, and thereafter for other life stages; no **attractant** available

CONTROL
Silvicultural: remove infested cones from seed orchard and destroy
Biological: none available; probably maintained at low denisities by parasitoids
Chemical: soil application of systemic insecticides has been effective in reducing populations

REFERENCES
Biology: Tripp (1955); Tripp and Hedlin (1956); Hedlin (1973, 1974); Hedlin *et al.* (1981); Brown and Amirault (1985); Churcher *et al.* (1985); Prévost *et al.* (1988)
Control: Fogal and Lopushanski (1984); Churcher *et al.* (1985); Fogal and Plowman (1989)

NOTES:

SPRUCE CONE AXIS MIDGE

Adult Y Prévost

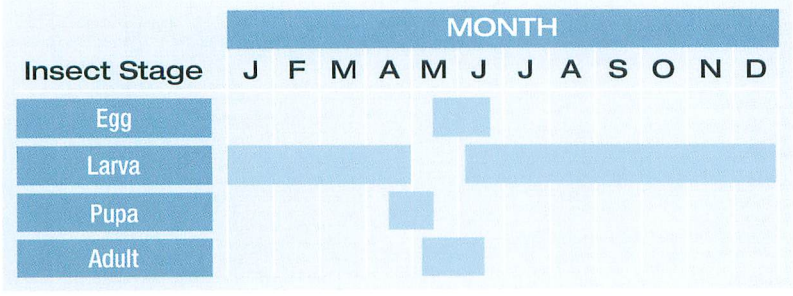
Pupa in white cocoon N Nelson

TAXONOMY

Order (Family): Diptera (Cecidomyiidae)
Scientific name: *Kaltenbachiola rachiphaga* (Tripp)
Synonym(s): *Dasineura rachiphaga* Tripp
French name: Cécidomyie des cônes de l'épinette

INSECT DESCRIPTION

Egg: whitish; 0.3 by 0.1 mm; oblong; laid at extreme base of seed cone scale or near the **rachis** when cones are open for pollination
Larva: three instars; yellowish-orange; about 3.0 mm long when mature; slightly dorso-ventrally flattened with small, faintly **sclerotized head capsule**; **spatula** present on underside near front end; head capsule no wider than spatula; without prominent lobes at hind end; antennae small; develops and overwinters in the cone rachis; capable of extended **diapause**
Pupa: whitish in early stages, turning darker as it matures; about 2.5 mm long;



antennal horn stout, rounded with one sharp tooth; found in a white cocoon in the same cavity as larva
Adult: dark brown; about 2.2 mm long; mosquito-like

HOSTS: Spruce (black, red, white)

DISTRIBUTION: found throughout the range of spruce
DAMAGE: larva creates a small cavity in the cone **axis**; this cavity does not affect the seed production or viability, but could disrupt the flow of nutrients to the seed
IMPORTANCE: up to 60% of the cones can be infested; 1 to 3 larva(e) per black spruce cone have little impact on seed production and viability; more than 5 larvae per cone could impact on seed production
DETECTION AND MONITORING: dissect cone before it closes completely to find egg, and thereafter for other life stages; no **attractant** available

CONTROL
Silvicultural: remove infested cones from seed orchard and destroy
Biological: none available; additional work is required with *B. bassiana* (Bals.) Vuill.; probably maintained at low densities by parasitoids
Chemical: folar application of systemic insecticides has been effective

REFERENCES
Biology: Tripp (1955); Tripp and Hedlin (1956); Ruth *et al.* (1980); Hedlin *et al.* (1981); Brown and Amirault (1985); Churcher *et al.* (1985); West (1985); Prévost (1990)
Control: Fogal and Lopushanski (1984); Churcher *et al.* (1985); Fogal *et al.* (1986a, 1986b); Prévost *et al.* (1988); Fogal and Plowman (1989)

NOTES:

SPRUCE SEED MIDGE

Pupa D Ruth

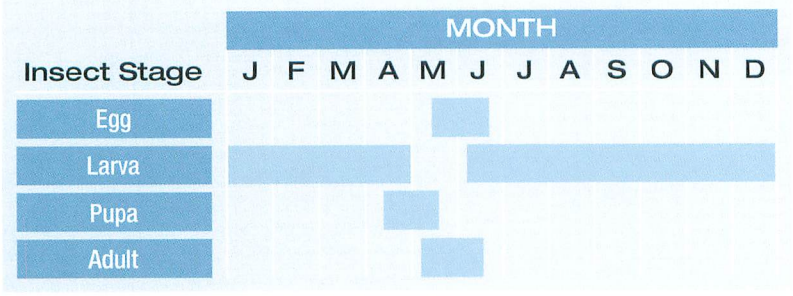
Larva in seed D Ruth

TAXONOMY

Order (Family): Diptera (Cecidomyiidae)
Scientific name: *Mayetiola carpophaga* (Tripp)
Synonym(s): *Phytophaga carpophaga* Tripp
French name: Cécidomyie séminivore de l'épinette

INSECT DESCRIPTION

Egg: whitish; 0.3 by 0.1 mm; oblong; smooth **chorion**; laid near young seed ovules on receptive cone scale during pollination
Larva: three instars; yellowish-pink; about 3.0 mm long when fully developed; slightly dorso-ventrally flattened with small, faintly **sclerotized head capsule**; **spatula** present on underside near front end; head capsule no wider than spatula; without prominent lobes at hind end; antennae small; develops and overwinters in the seed, within the cone on the tree, or on the ground; capable of extended **diapause**
Pupa: brownish; about 3.0 mm long; **antennal horn** short, with two small teeth



of unequal size, the larger of which has a small notch; found in a white cocoon in the seed
Adult: about 2.4 mm long; mosquito-like

HOSTS: Spruce (black, red, white)

DISTRIBUTION: found throughout the range of spruce
DAMAGE: the infested seed ovule becomes shiny brown, brittle, and distorted as the larva matures; infested seed is hollowed out and twice as large as normal seed, and cannot be extracted from the cone
IMPORTANCE: up to 35% of the seeds may be destroyed; individual trees can be heavily attacked; each larva destroys one seed
DETECTION AND MONITORING: dissect cone before it closes completely to find egg, and dissect seed thereafter for other life stages; no **attractant** available

CONTROL
Silvicultural: remove infested cones from seed orchard and destroy
Biological: none available
Chemical: stem injection of systemic insecticides has been effective in reducing damage

REFERENCES
Biology: Tripp (1955); Hedlin (1974); Ruth *et al.* (1980); Hedlin *et al.* (1981); Brown and Amirault (1985); Churcher *et al.* (1985)
Control: Churcher *et al.* (1985); Fogal and Plowman (1989)

NOTES:

CONE MIDGES

Larva Y Prévost

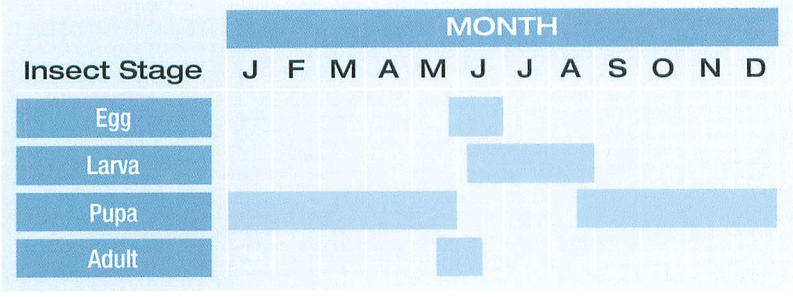
Damaged scale D Ruth

TAXONOMY

Order (Family): Diptera (Cecidomyiidae)
Scientific name: *Resseliella* spp.
Synonym(s):
French name: Cécidomyie des graines des cônes

INSECT DESCRIPTION

Egg: whitish; 0.5 mm long; cylindrical; on tamarack, laid on needles near seed cones, location unknown on spruce and pine
Larva: near white to orange; 1.5-3.5 mm long; slightly dorso-ventrally flattened with small, faintly **sclerotized head capsule**; **spatula** present on underside near front end; spatula with two lobes at front end; antennae small; two prominent, pointed lobes at hind end; develops in cone between scales
Pupa: brownish; overwinters in cones or in the forest litter
Adult: yellowish; about 2.0 mm long; mosquito-like



HOSTS: Larch (eastern); Spruce (black, red, white); Pine (jack, red, eastern white);

DISTRIBUTION: widely distributed
DAMAGE: cone scale(s) shrivelled, and brown; dried resin flakes on exterior and fluid resin between scales; larva leaves no frass; damaged seeds become brownish black and dry or are completely empty
IMPORTANCE: up to 5% of eastern larch and jack pine seed crops can be destroyed; undetermined on other species
DETECTION AND MONITORING: examine foliage near cone to find egg, dissect cone to find larvae; no **attractant** available

CONTROL
Silvicultural: none available
Biological: none available
Chemical: none available; soil and foliar applications of systemic insecticides have been unsuccessful

REFERENCES
Biology: Hedlin (1974); Hedlin *et al.* (1981); Brown and Amirault (1985); Churcher *et al.* (1985); West (1985); Amirault and Brown (1986); de Groot (1986); Hartling and O'Shea (1989)
Control: Amirault and Brown (1986)

NOTES:

BLACK SPRUCE CONE MAGGOT

Female ovipositing J Sweeney

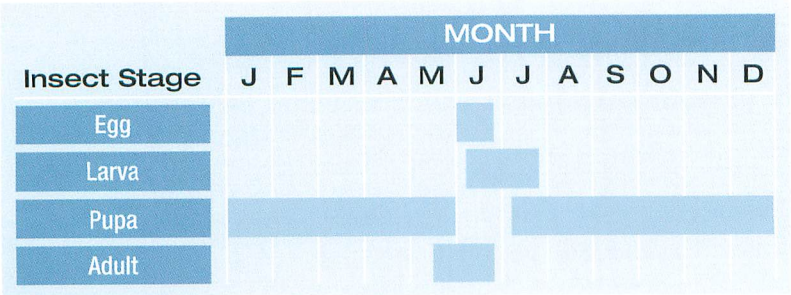
Egg between cone scales J Sweeney

TAXONOMY

Order (Family): Diptera (Anthomyiidae)
Scientific name: *Strobilomyia appalachensis* Michelsen
Synonym(s): *Lasiomma* (= *Hylemyia*= *Delia*= *Pegohylemyia*) *anthracina* (Czerny) in part
French name: Mouche granivore de l'épinette noire

INSECT DESCRIPTION

Egg: pearl white; 1.4 by 0.5 mm with distinct bulge on one side; laid singly between cone scales after scales have closed
Larva: three instars, the first **moult** occurs within the egg; creamy white; 4.9 by 1.1 mm when mature; cylindrical without definite **head capsule**; with small black hook-like mouthparts; **tubercules** present; develops in cone
Puparium: reddish brown; 4.0-6.0 by 1.2-1.4 mm, nearly ovoid; overwinters in soil under the tree; capable of extended **diapause**
Adult: black; wing length 4-5 mm; resembles a housefly



HOSTS: Spruce (black, red)

DISTRIBUTION: found throughout the range of black and red spruce
DAMAGE: infested cones usually smaller at maturity than healthy cones; small hole on cone surface in July after larva exits cone; larva tunnels around cone **axis** consuming scales and seeds; tunnel contains resin and frass
IMPORTANCE: between 5-100% of cones can be attacked; one larva can destroy 50-75% of filled seeds per cone; two or more larvae usually destroy 100% of seeds per cone;
DETECTION AND MONITORING: dissect cone when 1/2 to 3/4 pendant to find eggs, and thereafter until late July to find larvae; colour trap is being developed for adults

CONTROL
Silvicultural: none available
Biological: none available
Chemical: foliar applications and tree implants of systemic insecticides have been effective at reducing populations.

REFERENCES
Biology: Turgeon and Sweeney (1993); Sweeney and Turgeon (1994); Fidgen and Sweeney (1996); Fidgen *et al.* (1998,1999)
Control: Churcher *et al.* (1985); Prévost *et al.* (1988); West and Sundaram (1992); Sweeney and Gesner (1995); Sweeney *et al.* (2002)

NOTES:

LARCH CONE MAGGOT

Egg between bud scales J Turgeon

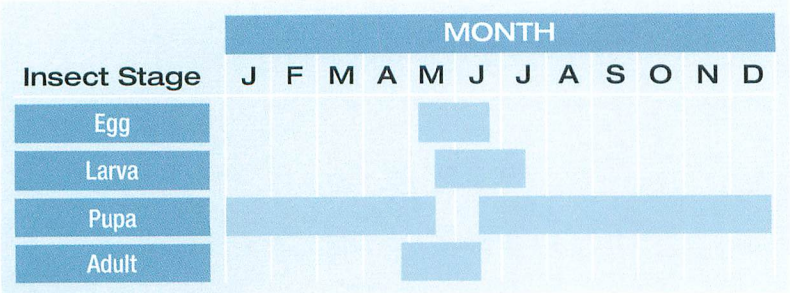
Larva T Arcand

TAXONOMY

Order (Family): Diptera (Anthomyiidae)
Scientific name: *Strobilomyia laricis* Michelsen
Synonym(s): *Lasiomma laricicola* (Karl)
French name: Mouche granivore du mélèze

INSECT DESCRIPTION

Egg: creamy white; beige; 1.0 by 0.4 mm; nearly ovoid with a patterned surface and one end flat; laid singly between the seed cone curled bud scales
Larva: three instars, the first **moult** occurs within the egg; creamy white; 4.0-6.0 by 1.5 mm; cylindrical without definite **head capsule**; **tubercules** present; develops in cone
Puparium: reddish-brown; 3.0-5.0 by 1.2 mm; nearly ovoid; overwinters in soil under tree; capable of extended **diapause**
Adult: black; wing length 3.7-4.3 mm; resembles a housefly



HOST: Larch (eastern)

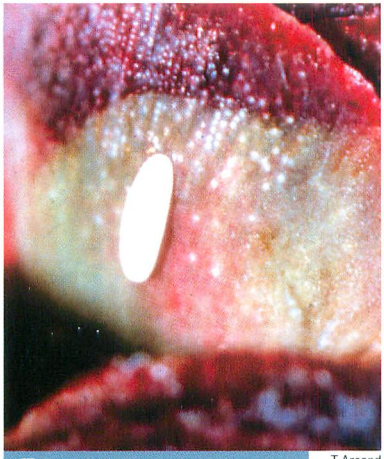
DISTRIBUTION: found throughout the range of eastern larch
DAMAGE: attacked cone appears similar to healthy cone; larva tunnels around the cone **axis** and feeds on seeds and scales, leaving large amount of filamentous and coarse **frass**
IMPORTANCE: attacks are localized, with up to 100% of the cones attacked even when cones are abundant; one larva can destroy 100% of the filled seeds per cone
DETECTION AND MONITORING: examine the scales at the base of cone to find egg, and dissect cone for larva; colour trap is being developed for adults

CONTROL
Silvicultural: none available
Biological: none available
Chemical: foliar and soil applications of systemic insecticides have been effective in reducing damage

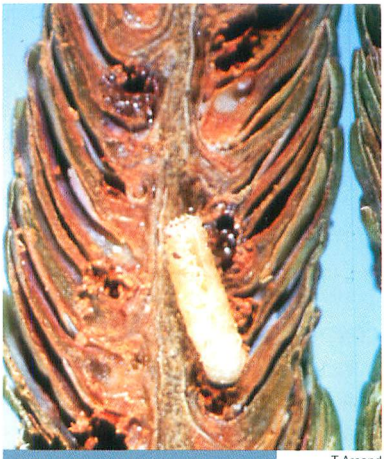
REFERENCES
Biology: Popova and Elberg (1970); Stadnitsky *et al.* (1976); Hedlin *et al.* (1981); Amirault and Brown (1986); Ives and Wong (1988); Michelsen (1988); Turgeon (1989); Chau (1993); McClure *et al.* (1996,1998); Prévost (2002)
Control: Stadnitsky *et al.* (1976); Amirault and Brown (1986)

NOTES:

WHITE SPRUCE CONE MAGGOT



Egg between cone scales T Arcand



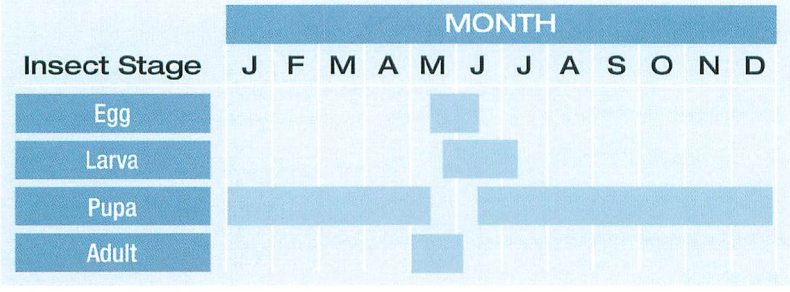
Larva in damaged cone T Arcand

TAXONOMY

Order (Family): Diptera (Anthomyiidae)
Scientific name: *Strobilomyia neanthracina* Michelsen
Synonym(s): *Lasiomma* (= *Hylemyia* = *Delia* = *Pegohylemyia*) *anthracina* (Czerny) in part
French name: Mouche granivore de l'épinette blanche

INSECT DESCRIPTION

Egg: pearl white; 1.6 by 0.5 mm; nearly ovoid with one end flat; laid singly between cone scales during pollination
Larva: three instars, the first **moult** occurs within the egg; creamy white; 5.0-7.0 by 1.5 mm when mature; cylindrical without definite **head capsule**; **tubercules** present; develops in cone
Puparium: reddish-brown; 4.0-6.0 by 1.2-1.4 mm; nearly ovoid; overwinters in soil under tree; capable of extended diapause
Adult: black; wing length 3.9-4.6 mm; resembles a housefly



HOST: Spruce (white)

DISTRIBUTION: found throughout the range of white spruce
DAMAGE: infested cone usually smaller than healthy one; small hole found on cone surface in late June or early July after larva leaves cone; larva tunnels around cone **axis** and fills it with **frass** and resin; larva consumes scales and seeds
IMPORTANCE: between 40-100% of the cones can be attacked; one larva can destroy 55-65% of the filled seeds per cone, respectively; two or more larvae usually destroy 100% of the seeds per cone
DETECTION AND MONITORING: dissect cone shortly after it closes to find egg, and thereafter until late July to find larvae; colour trap is being developed for adults

CONTROL
Silvicultural: none available
Biological: none available; additional work is required with *B. bassiana* (Bals.) Vuill
Chemical: foliar spray, tree implant, and stem injection of systemic insecticides have been effective in reducing populations

REFERENCES
Biology: Tripp (1954a); Popova and Elberg (1970); Hedlin *et al.* (1981); Brown and Amirault (1985); Churcher *et al.* (1985); West (1985); Fogal (1986); Fogal *et al.* (1986a); Ives and Wong (1988); Michelsen (1988); Prévost *et al.* (1988); Hartling and O'Shea (1989); Miller *et al.* (1995); Sweeney (1996a, 1996b); Fidgen *et al.* (1998); Sweeney and Quiring (1998); Quiring *et al.* (1998); Brockerhoff *et al.* (1999)
Control: Timonin *et al.* (1980); Churcher *et al.* (1985); Fogal and Lopushanski (1984,1989); Fogal (1986); Fogal *et al.* (1986a,1986b); Prévost *et al.* (1988); Fogal and Plowman (1989); Sweeney *et al.* (1998, 2002)

NOTES:

TAMARACK CONE MAGGOT

Egg between cone scales N Nelson

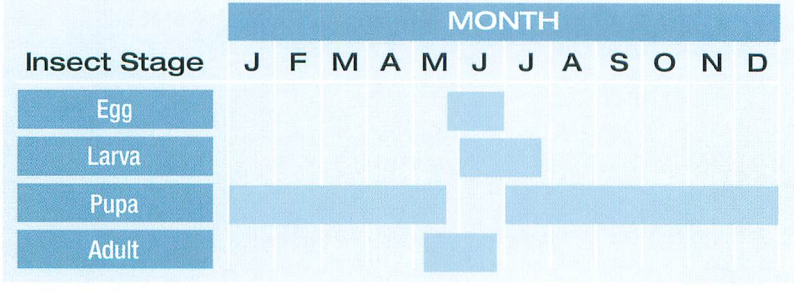
Larva attacking seed J Sweeney

TAXONOMY

Order (Family): Diptera (Anthomyiidae)
Scientific name: *Strobilomyia viaria* (Huckett)
Synonym(s): *Lasiomma* (= *Hylemyia* = *Delia*) *viarium* Huckett
French name: Mouche granivore du mélèze laricin

INSECT DESCRIPTION

Egg: pearl white; 1.1 by 0.3 mm; nearly ovoid with a smooth surface and one end flat; laid singly on inner surface or between cone scales just above the ovules
Larva: three instars, the first **moult** occurs within the egg; creamy white; 4.0-6.0 by 1.5 mm; cylindrical without definite **head capsule**; can be differentiated from *S. laricis* by the shape of the mouthparts; **tubercules** present; develops in cone
Puparium: reddish-brown; 3.0-5.0 by 1.2 mm; nearly ovoid; overwinters in soil under tree; capable of extended **diapause**
Adult: black; wing length 3.3-4.0 mm; resembles a housefly



HOST: Larch (eastern)

DISTRIBUTION: found throughout the range of eastern larch
DAMAGE: attacked cone appears similar to healthy cone; larva tunnels around the cone **axis** and feeds on seeds and scales, leaving large amount of filamentous **frass**
IMPORTANCE: attacks are localized, with up to 100% of the cones attacked; one larva can destroy 100% of the filled seeds per cone
DETECTION AND MONITORING: dissect the cone to find egg and larva; no trap available; colour trap is being developed for adults

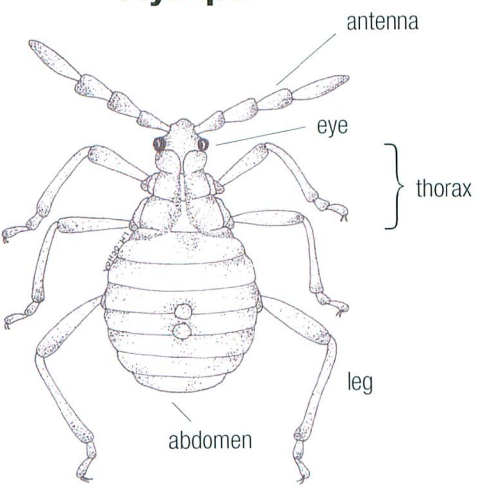
CONTROL
Silvicultural: none available
Biological: none available
Chemical: foliar and soil applications of systemic insecticides have been effective in reducing damage

REFERENCES
Biology: Popova and Elberg (1970); Stadnitsky *et al.* (1976); Hedlin *et al.* (1981); Brown and Amirault (1985); Amirault and Brown (1986); Ives and Wong (1988); Michelsen (1988); Turgeon (1989); Chau (1993); McClure *et al.* (1996,1998)
Control: Stadnitsky *et al.* (1976); Amirault and Brown (1986)

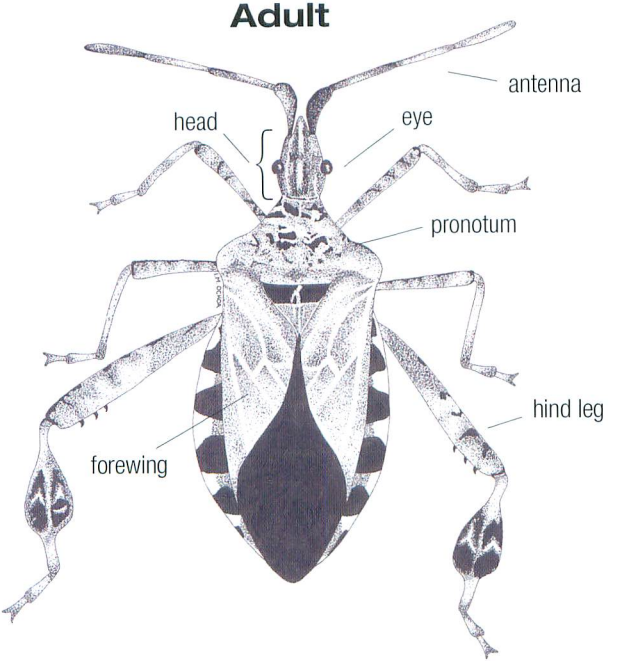
NOTES:

HEMIPTERA

Nymph



Adult



WESTERN CONIFER SEED BUG

Adult on cone D Ruth

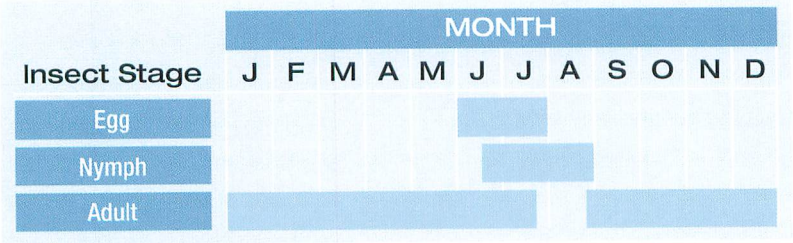
Eggs and nymph emerging D Ruth

TAXONOMY

Order (Family): Hemiptera (Coreidae)
Scientific name: *Leptoglossus occidentalis* Heidemann
Synonym(s):
French name: Punaise séminivore de l'ouest

INSECT DESCRIPTION

Egg: light brown becoming reddish brown near hatch; about 2.0 mm long; barrel shaped; glued in a row of 4-5 per needle on host foliage
Nymph: five stages; orange to reddish brown; resembles miniature adult but without wings; found on cone surface
Adult: reddish brown to dark gray with distinctive white wavy line across the **forewings** and five dark patches down each side of the abdomen; 15.0 to 18.0 mm long with long, flattened hind legs; found on cone surface; makes loud buzzing sound when flying; overwinters in sheltered locations, including houses; emits noxious odour when disturbed



HOSTS: Pine (red, white); Hemlock (eastern)

DISTRIBUTION: found from British Columbia to as far east as Nova Scotia
DAMAGE: Exterior of cone appears normal; nymphs and adults pierce developing cones and seeds with needle-like mouthparts and feed on **endosperm**; damaged seeds evident only through use of X-rays and specialized biochemical antibody assays
IMPORTANCE: impact on eastern pines unknown but can damage up to 70% of seeds in lodgepole pine and Douglas-fir in western Canada; also damages pollen cones
DETECTION AND MONITORING: visual inspection for **nymphs** and adults on cones and foliage; no **attractant** available; evidence for male-produced aggregation pheromone

CONTROL
Silvicultural: none available
Biological: none available
Chemical: foliar applications of insecticides have been effective in reducing densities and seed losses. Stem-injections of systemic insecticides have reduced damage by *Leptoglossus corculus* (Say), in southern pines

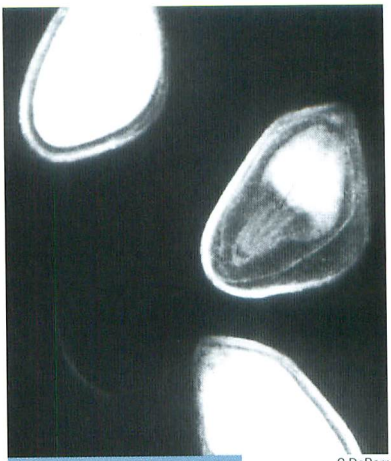
REFERENCES
Biology: Koerber (1963); Hedlin *et al.* (1981); Rauf *et al.* (1985); Katovich and Kulman (1987b); Campbell and Shea (1990); McPherson *et al.* (1990); Connelly and Schowalter (1991); Marshall (1991); Gall (1992); Blatt and Borden (1996a, 1996b, 1999); Bates *et al.* (2000, 2001); Lait *et al.* (2001)
Control: Nord and DeBarr (1992); Rappaport *et al.* (1994); Strong *et al.* (2001); Grosman *et al.* (2002)

NOTES:

SHIELD-BACKED PINE SEED BUG

Adult

P de Groot



Damaged seed

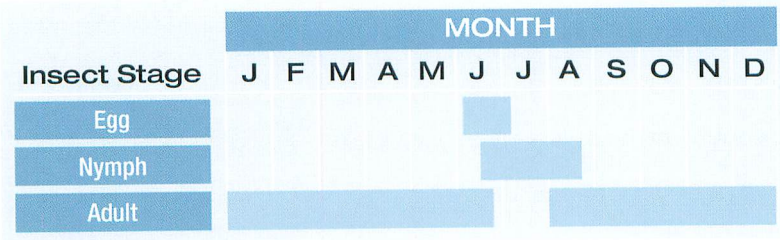
G DeBarr

TAXONOMY

Order (Family): Hemiptera (Scutellaridae)
Scientific name: *Tetyra bipunctata* (Herrich-Schäffer)
Synonym(s):
French name: Tétyre biponctuée

INSECT DESCRIPTION

Egg: pale green, changing to reddish as embryo develops; 1.7 by 1.4 mm; ovoid to nearly spherical; laid on cones or in two parallel rows on needles
Nymph: five stages; grayish when young, becoming reddish-brown with black mottling as they mature; broadly oval, flat in appearance; found on cone surface
Adult: yellowish to dark reddish-brown; densely marked with pits and gray-black mottling; 11.0-15.0 mm long; oval-shaped; overwinters in loose bark, logs, or soil



HOSTS: Pine (eastern white, jack, red)

DISTRIBUTION: found throughout the range of pine
DAMAGE: exterior of cone appears normal; seeds attacked before the seed coat becomes hard are small and flat, those attacked after are completely or partially empty
IMPORTANCE: typically up to 10% of the cones, and 85% of seeds per cone, are damaged
DETECTION AND MONITORING: visual inspection or sieving of soil and litter for adults in fall; extract and irradiate (x-ray) the seed to assess seed loss; no **attractant** available

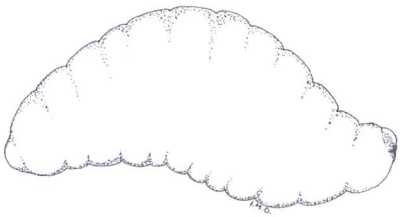
CONTROL
Silvicultural: none available
Biological: none available; ground and aerial applications of *B.t.* have been ineffective
Chemical: foliar and soil applications of systemic insecticides have been effective in reducing damage

REFERENCES
Biology: Gilbert *et al.* (1967); DeBarr (1970); DeBarr and Ebel (1973); Cameron (1981); Goyer and Williams (1981); Hedlin *et al.* (1981); Brown and Amirault (1985); Rauf *et al.* (1985); Katovich and Kulman (1987a, 1987b)
Control: DeBarr (1978, 1979); Cameron (1981); Nord *et al.* (1984); Cameron *et al.* (1987); Fogal and Plowman (1989)

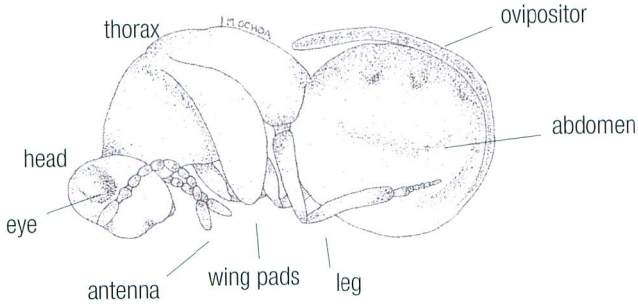
NOTES:

HYMENOPTERA

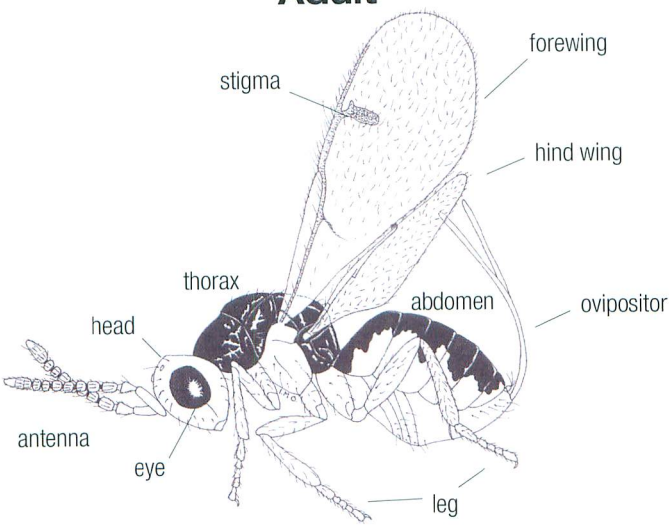
Larva



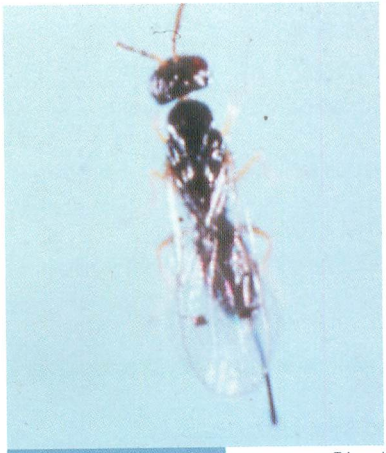
Pupa



Adult



SPRUCE SEED CHALCID

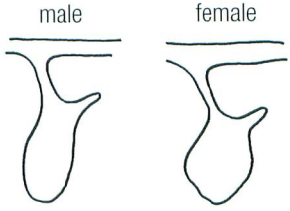


Adult female T Arcand

Exit hole T Arcand

TAXONOMY

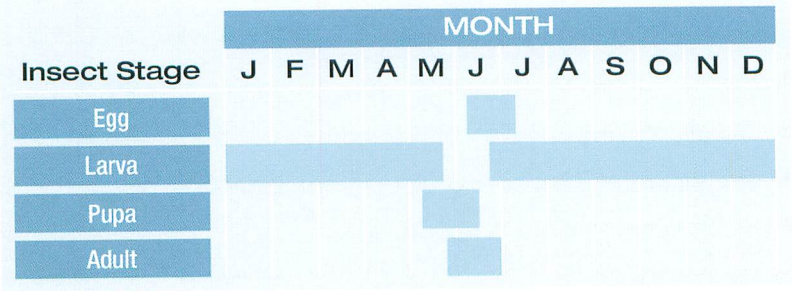
Order (Family): Hymenoptera (Torymidae)
Scientific name: *Megastigmus atedius* Walker
Synonym(s): *Megastigmus piceae* Rohwer
French name: Chalcis granivore de l'épinette



Shape of stigma

INSECT DESCRIPTION

Egg: white; elliptical
Larva: five instars; 2.7-3.0 mm long at maturity; white, with dark brown to black mandibles; curved; legless; segmented; feeds in one seed throughout the summer (6-8 weeks); overwinters in the seed within the cone on the tree, or on the ground; capable of extended **diapause**
Pupa: no description available
Adult: body black with yellow markings on thorax; female (2.5-3.0 mm long)-male (2.0-2.7 mm long); membranous wings with **stigma**; (see shape above);



female has noticeably long **ovipositor**

HOSTS: Spruce (black, red, white); Pine (possibly eastern white)

DISTRIBUTION: found throughout the range of spruce
DAMAGE: attacked seeds are similiar to healthy seeds; content of each seed entirely consumed
IMPORTANCE: typically less than 10% of the cones are attacked; each larva destroys one seed
DETECTION & MONITORING: dissect seed to find egg, larva and pupa; extract and irradiate (x-ray) seed to assess infestation level; no **attractant** available

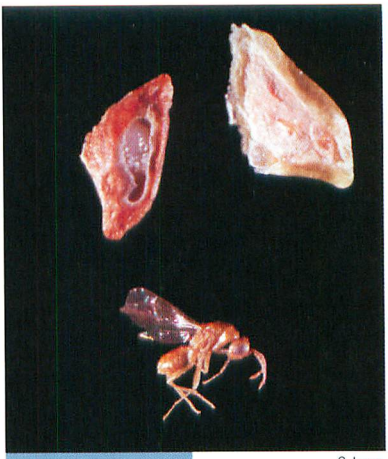
CONTROL
Silvicultural: none available
Biological: none available
Chemical: stem injection of systemic insecticides has been effective in reducing damage; soil application of systemic insecticides has been unsuccessful

REFERENCES
Biology: Milliron (1949); Hedlin (1973,1974); Speers (1974); Ruth *et al.* (1980); Hedlin *et al.* (1981); Brown and Amirault (1985); Churcher *et al.* (1985); Roques and Skrzypczynska (2003)
Control: DeBarr *et al.* (1982); Fogal and Plowman (1989)

NOTES:

HEMLOCK SEED CHALCID

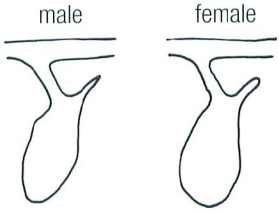
Adult male and female C Jones



Seed infested C Jones

TAXONOMY

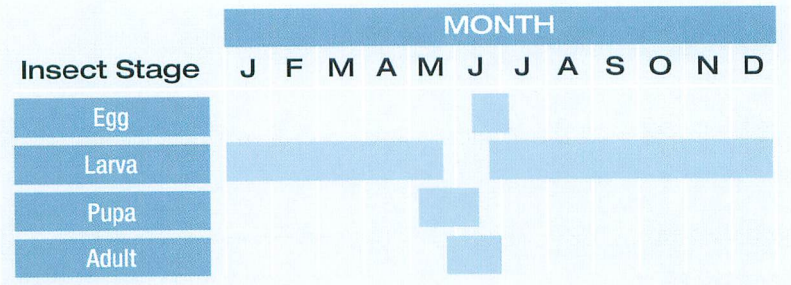
Order (Family): Hymenoptera (Torymidae)
Scientific name: *Megastigmus hoffmeyeri* Walley
Synonym(s):
French name: Chalcis séminivore de la pruche



Shape of stigma

INSECT DESCRIPTION

Egg: no description available
Larva: five instars; white, with dark brown to black mandibles; curved; legless; segmented; feeds in one seed throughout the summer (6-8 weeks); overwinters in the seed within the cone on the tree, or on the ground; capable of extended **diapause**
Pupa: brown; found in seeds on the ground
Adult: body brownish yellow; female (1.9-3.3 mm long) - male (0.7-1.4 mm long); membranous wings with **stigma** (see shape above); female has noticeably long **ovipositor**



HOSTS: Hemlock (eastern, Carolina)

DISTRIBUTION: found throughout the range of eastern hemlock
DAMAGE: attacked seeds are similiar to healthy seeds;
content of each seed entirely consumed
IMPORTANCE: cone attack can reach 40%; typically, less than 6% of the seed crop is attacked; each larva destroys one seed
DETECTION AND MONITORING: dissect seed to find egg, larva and pupa;
extract and irradiate (x-ray) seed to assess infestation level; no **attractant** available

CONTROL
Silvicultural: none available
Biological: none available
Chemical: none available

REFERENCES
Biology: Milliron (1949); Turgeon *et al.* (2004)
Control: none available

NOTES:

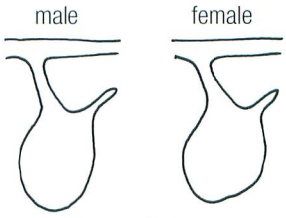
LARCH SEED CHALCID

Adult female — Canadian Forest Service

Exit hole — T Arcand

TAXONOMY

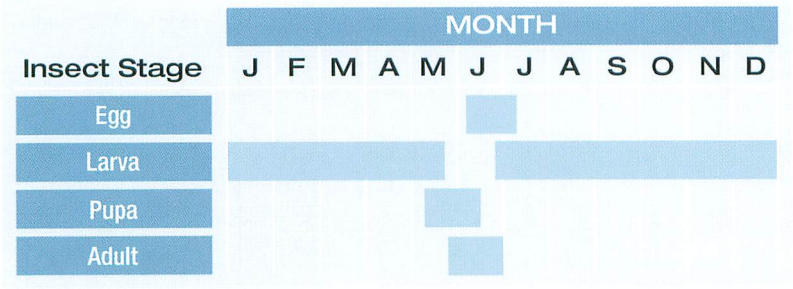
Order (Family): Hymenoptera (Torymidae)
Scientific name: *Megastigmus laricis* Marcovitch
Synonym(s):
French name: Chalcis séminivore du mélèze



Shape of stigma

INSECT DESCRIPTION

Egg: white; 0.22 mm long; spindle-shaped; smooth; laid in seed
Larva: five instars; 2.1 by 0.9 mm at maturity; white, with dark brown to black mandibles; curved; legless; mandible has 4 teeth; segmented; feeds in one seed throughout the summer (6-8 weeks); overwinters in the seed within the cone on the tree, or on the ground; capable of extended **diapause**
Pupa: brown; found in seeds within the cone on the tree or on the ground
Adult: body black and tawny yellow; female (2.1 mm long) - male (2.5 mm long);



membranous wings with **stigma** (see shape above); female has noticeably long **ovipositor**

HOST: Larch (eastern)

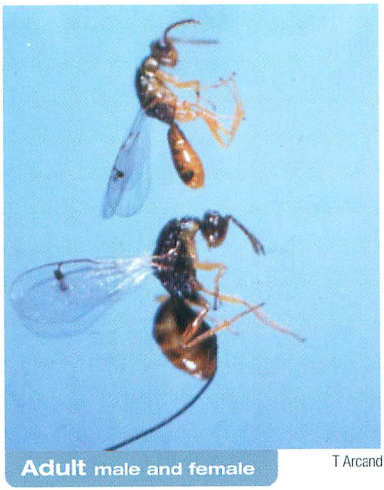
DISTRIBUTION: found throughout the range of eastern larch
DAMAGE: attacked seeds are similiar to healthy seeds; content of each seed entirely consumed
IMPORTANCE: up to 20% of the cones can be attacked; up to 10% of seed crop can be destroyed; each larva destroys one seed
DETECTION AND MONITORING: dissect seed to find egg, larva and pupa; extract and irradiate (x-ray) seed to assess infestation level; no **attractant** available

CONTROL
Silvicultural: none available
Biological: none available
Chemical: none available; foliar and soil applications of systemic insecticides have been unsuccessful

REFERENCES
Biology: Marcovitch (1914); Milliron (1949); Hedlin (1974); Brown and Amirault (1985); Amirault and Brown (1986)
Control: Amirault and Brown (1986)

NOTES:

BALSAM FIR SEED CHALCID

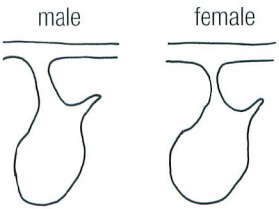


Adult male and female T Arcand

Adult exiting seed T Arcand

TAXONOMY

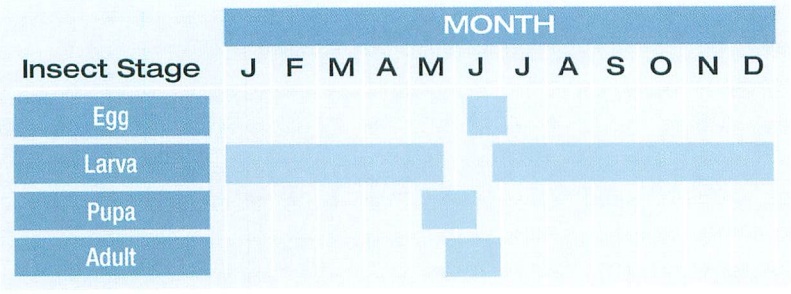
Order (Family): Hymenoptera (Torymidae)
Scientific name: *Megastigmus specularis* Walley
Synonym(s):
French name: Chalcis granivore du sapin baumier



Shape of stigma

INSECT DESCRIPTION

Egg: milky-white; 0.29 by 0.15 mm; elongate-oval with 2 **pedicels** (about 0.91 and 0.03 mm long, respectively); smooth and glossy; laid in seed
Larva: five instars; yellowish-white, with dark brown to black mandibles; 1.31-4.20 mm long at maturity; curved (strongly arched and tapered at both ends); legless; segmented; feeds in one seed throughout the summer (6-8 weeks); overwinters in the seed on the ground; capable of extended **diapause**
Pupa: entirely white when newly formed with eyes turning from pale orange



to deep crimson within a few days; female (2.88 by 1.11 mm long)-
male (2.50 by 0.98 mm long); found in seeds on the ground
Adult: body black and tawny yellow; female (2.2-3.8 mm long)- male
(2.1-3.0 mm long); membranous wings with **stigma**
(see shape on previous page); female has noticeably long **ovipositor**

HOSTS: Fir (balsam, Fraser)

DISTRIBUTION: found throughout the range of balsam fir
DAMAGE: attacked seeds are similiar to healthy seeds;
content of each seed entirely consumed
IMPORTANCE: up to 57% of seed crop can be attacked; each larva destroys one seed
DETECTION AND MONITORING: dissect seed to find egg, larva and pupa; extract and irradiate (x-ray) seed to assess infestation level; no **attractant** available

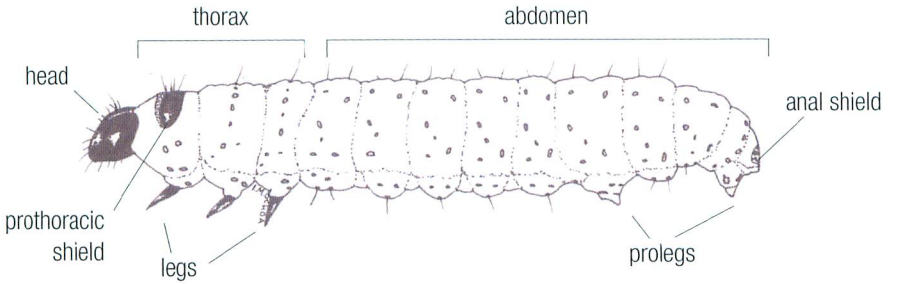
CONTROL
Silvicultural: none available
Biological: none available
Chemical: none available

REFERENCES
Biology: Milliron (1949); Hedlin (1956); Kettela (1967);
Roques and Skrzypczynska (2003)
Control: none available

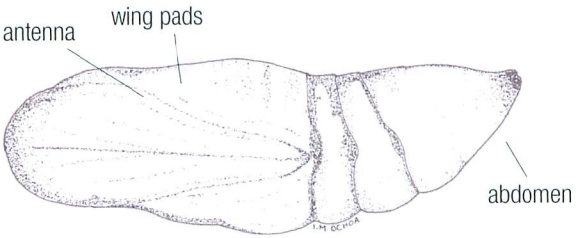
NOTES:

LEPIDOPTERA

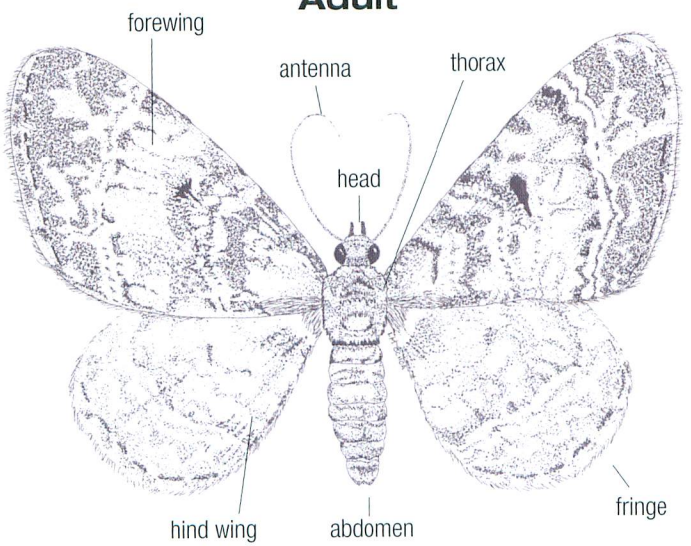
Larva



Pupa

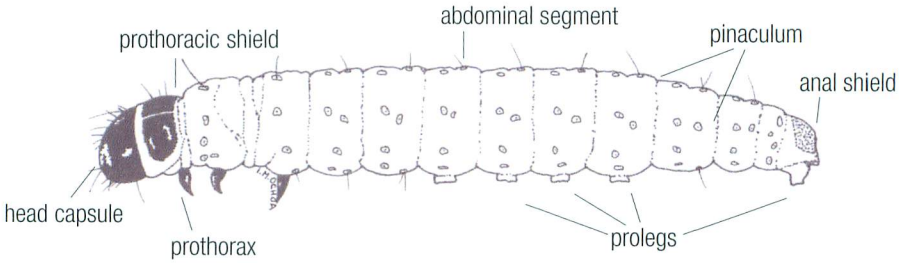


Adult

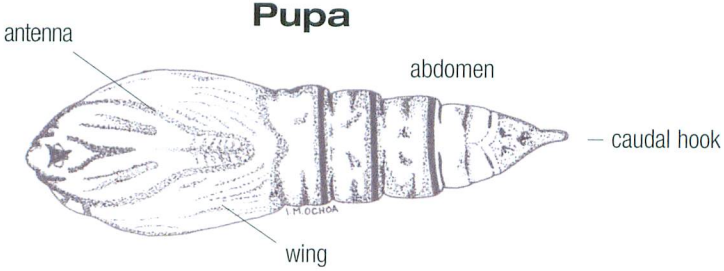


LEPIDOPTERA

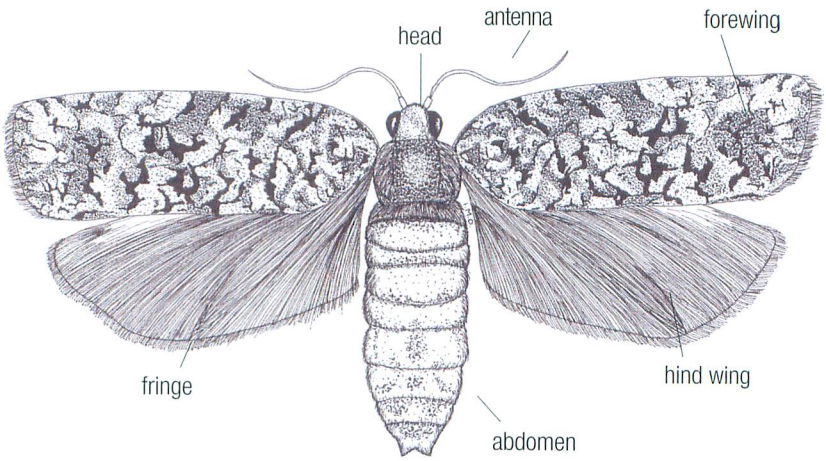
Larva



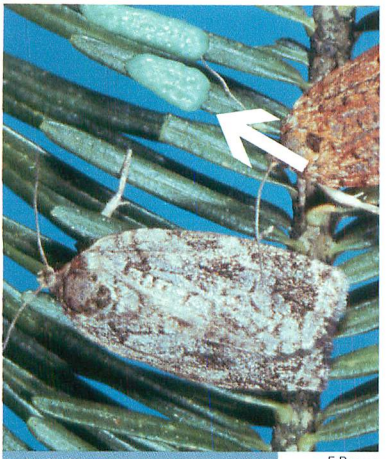
Pupa



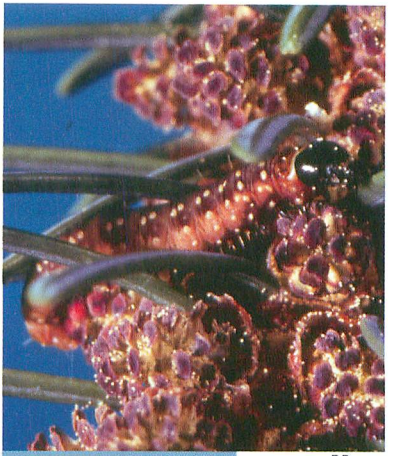
Adult



EASTERN SPRUCE BUDWORM



Adult and egg masses E Rayner



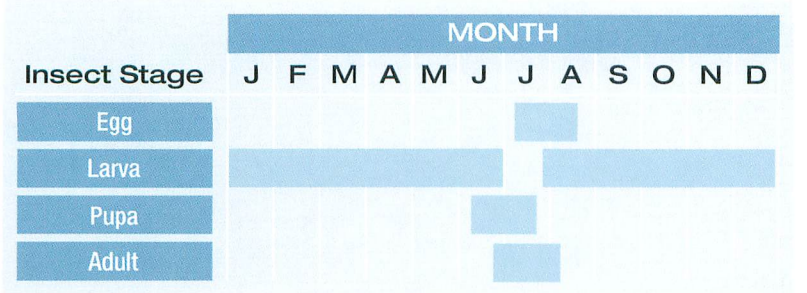
Larva (last instar) E Rayner

TAXONOMY

Order (Family): Lepidoptera (Tortricidae)
Scientific name: *Choristoneura fumiferana* (Clemens)
Synonym(s): *Archips fumiferana* Clemens
French name: Tordeuse des bourgeons de l'épinette

INSECT DESCRIPTION

Egg: bluish-green; about 1.0 mm long; flattened and ovoid; laid in masses of two to four rows, on the underside of the needles, with each mass containing about 20 eggs
Larva: six instars; first instar is yellowish with dark brown head; last instar is reddish-brown with two rows of whitish spots along the back and has dark brown **prothoracic shield** and legs; 18.0-24.0 mm long when mature; develops on foliage or in cone and overwinters as second instar in **hibernaculum**
Pupa: yellow to reddish-brown; attached to foliage
Adult: brownish-gray to gray, with mottled wing pattern; 20.0-30.0 mm wingspan



HOSTS: Fir (balsam); occasionally Larch (eastern); Spruce (red, black, white)

DISTRIBUTION: found throughout the range of white spruce
DAMAGE: cone is partially to completely consumed; webbing and coarse **frass** adhering to surface of cone and surrounding needles
IMPORTANCE: up to 100% of the seed cones of certain tree species can be destroyed; when at epidemic levels, the spruce budworm is one of the most serious pests of cones of several conifers in eastern Canada
DETECTION AND MONITORING: examine foliage to find egg masses and larva; examine seed cone at bud burst and thereafter, to find larva; sticky or bucket trap baited with sex **pheromone** is available

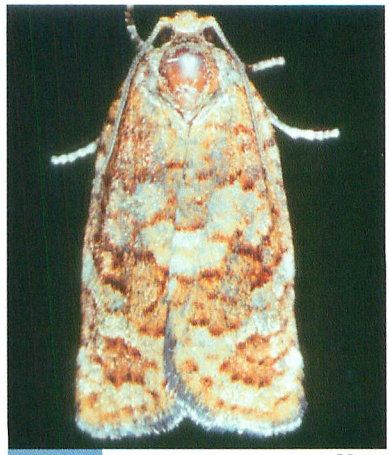
CONTROL
Silvicultural: none available
Biological: foliar application of *B.t.* has been effective in reducing populations and defoliation
Chemical: foliar and soil applications of systemic insecticides have been effective in reducing damage

REFERENCES
Biology: Campbell (1953); MacKay (1953); Silk *et al.* (1980); Hedlin *et al.* (1981); Brown and Amirault (1985); Churcher *et al.* (1985); Prévost *et al.* (1988)
Control: Churcher *et al.* (1985); Fogal and Plowman (1989)

NOTES:

JACK PINE BUDWORM

Larva E Rayner



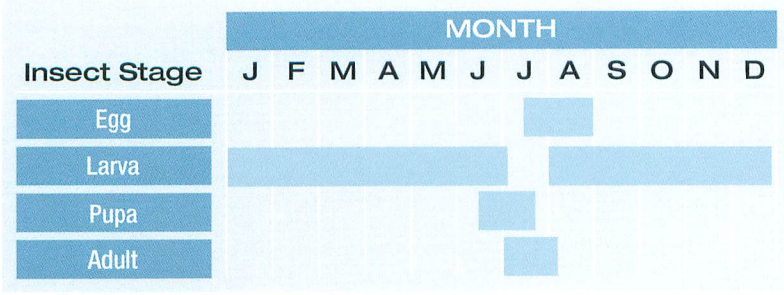
Adult E Rayner

TAXONOMY

Order (Family): Lepidoptera (Tortricidae)
Scientific name: *Choristoneura pinus pinus* Freeman
Synonym(s):
French name: Tordeuse du pin gris

INSECT DESCRIPTION

Egg: yellow-green; laid in two rows on underside of needles in clusters of about 40
Larva: seven instars; last instar has brownish to yellow head with two rows of white dots along the back, a dark brown almost black **prothoracic shield**, and a yellowish **anal shield**; 20.0-22.0 mm long; overwinters as second instar in **hibernaculum**
Pupa: dark gray or dark brown; attached to shoots or within webbed foliage
Adult: tawny gray with mottled wing patterns



HOSTS: Pine (jack, red, scotch, eastern white)

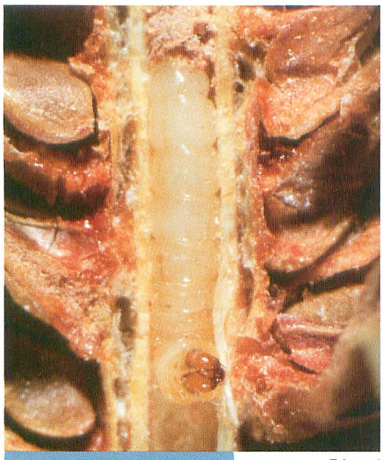
DISTRIBUTION: found throughout the range of jack pine
DAMAGE: one or more holes can be present on cone surface; feeding on cone surface and surrounding needles, with **frass** and webbing adhering to remaining needles; cone can be distorted due to destroyed conductive tissue
IMPORTANCE: significant loss of young pollen and seed cones may occur
DETECTION AND MONITORING: dissect cone to find larva; sticky or bucket trap baited with sex **pheromone** is available

CONTROL
Silvicultural: none available
Biological: foliar application of *B.t.* has been effective in reducing populations and defoliation
Chemical: foliar applications of contact insecticides have been effective in reducing damage

REFERENCES
Biology: Hodson and Zehngroff (1946); Campbell (1953); MacKay (1953); Walley (1953); Benjamin and Drooz (1954); Drooz and Benjamin (1956); Kulman and Hodson (1961); Dixon and Benjamin (1963); Benyus (1983); Silk *et al.* (1985); Nealis (1990)
Control: Cadogan *et al.* (1986)

NOTES:

SPRUCE SEED MOTH



Larva in cone axis T Arcand

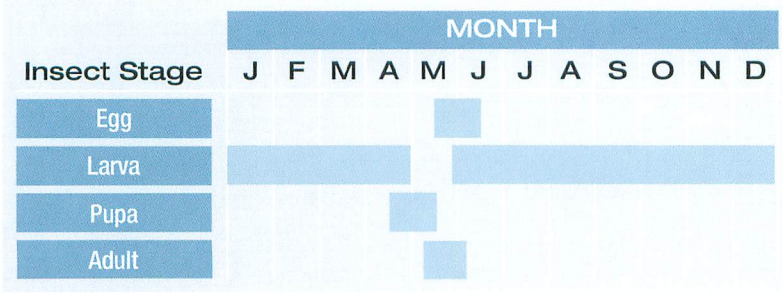
Damage T Arcand

TAXONOMY

Order (Family): Lepidoptera (Tortricidae)
Scientific name: *Cydia strobilella* Linneaus
Synonym(s): *Cydia* (=*Laspeyresia*) *youngana* Kearfott
French name: Tordeuse des graines de l'épinette

INSECT DESCRIPTION

Egg: pale to dark orange; about 0.5 mm in diameter; spherical, but become flat after cone scales close; laid in small overlapping clusters between cone scales near apex of seed cone
Larva: four instars; creamy white with a brown head and **prothoracic shield**; about 10.0 mm long when mature; overwinters in cone **axis**; capable of extended diapause for up to 3 years
Pupa: light amber turning deep brown to black prior to emergence; about 5.5 mm long with males usually 0.8 mm shorter than females; found in cone axis



Adult: smoky brown with four cross-bands of silver and four shining **coastal spots** on forewing; 8.0-11.0 mm wingspan

HOSTS: Spruce (white - occasionally black, red)

DISTRIBUTION: found throughout the range of spruce
DAMAGE: no external evidence of damage; internally, seeds are partially to completely consumed and fused to the scale; silken tunnels between seed pairs are evident
IMPORTANCE: up to 70% of the cone crop can be destroyed; each larva destroys about one third of the seeds in a cone
DETECTION AND MONITORING: dissect cone to find egg, larva, pupa; sticky trap baited with sex **pheromone** is available

CONTROL
Silvicultural: remove infested cones from the seed orchard and destroy
Biological: none available
Chemical: foliar and soil applications, stem injections and implants of systemic insecticides have been effective in reducing damage

REFERENCES
Biology: Tripp (1954b); Tripp and Hedlin (1956); Hedlin (1973); Ruth *et al.* (1980); Hedlin *et al.* (1981); Brown and Miller (1983); Fogal and Lopushanski (1984); Brown and Amirault (1985); Churcher *et al.* (1985); Grant *et al.* (1989)
Control: Fogal and Lopushanski (1984); Churcher *et al.* (1985); Fogal *et al.* (1986b) Fogal and Plowman (1989)

NOTES:

EASTERN PINE SEED MOTH

Larva feeding through scale P de Groot

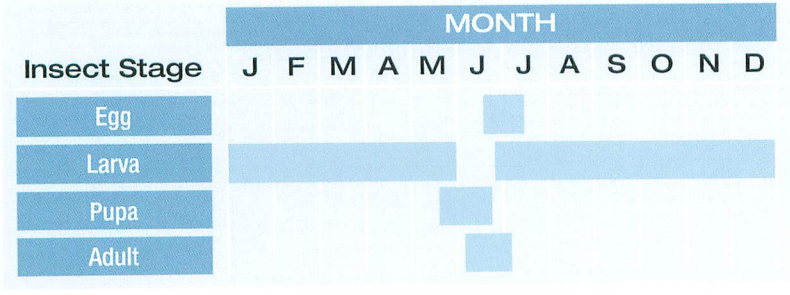
Larval exit hole P de Groot

TAXONOMY

Order (Family): Lepidoptera (Tortricidae)
Scientific name: *Cydia toreuta* (Groté)
Synonym(s): *Laspeyresia* toreuta (Groté)
French name: Tordeuse séminivore des pins

INSECT DESCRIPTION

Egg: white; about 0.2 by 0.3 mm; ovoid with **reticulated** flat surface; laid between cone scales
Larva: four instars; yellowish-white; last instar is about 10.0 mm long; body devoid of easily visible **setae**; slender body; develops in second-year cones
Pupa: 6.0-8.0 mm long; pointed head; posteriorly projecting spines on the dorsum of the **abdominal segments**; remains in the cone or drops to the ground
Adult: chocolate brown with two black-bordered silver bands on **forewing**; 12.0-15.0 mm wingspan



HOSTS: Pine (jack, red)

DISTRIBUTION: found throughout the range of pine
DAMAGE: no external evidence of damage; internally, larva tunnels between seeds and cone **axis**, leaving a trail which appears as brown lines against the white internal cone material; larva invariably approaches a seed at its upper end; seed coat of attacked seeds is partially destroyed; the remainder of seed coat is glued to the scale and filled with a mixture of **frass** and resin
IMPORTANCE: 15-80% of the cones can be attacked; up to 75% of the seeds per cone can be destroyed; one larva can destroy as many as 8 seeds
DETECTION AND MONITORING: dissect cone to find egg and larva; no **attractant** available

CONTROL
Silvicultural: remove infested cones from the seed orchard and destroy
Biological: *B.t.* and *Beauvaria bassiana* dusted on cones can be effective
Chemical: stem injection, implants, foliar sprays, and soil applications of systemic insecticides have been effective in reducing damage

REFERENCES
Biology: Lyons (1957b,1957c); Hard (1964); Kraft (1968); Ebel *et al.* (1980); Hedlin *et al.* (1981); Brown and Amirault (1985); Katovich and Kulman (1987a); Katovich *et al.* (1989)
Control: Cameron *et al.* (1987); Rush *et al.* (1987); Fogal and Plowman (1989)

NOTES:

FIR CONEWORM

Adult T Arcand

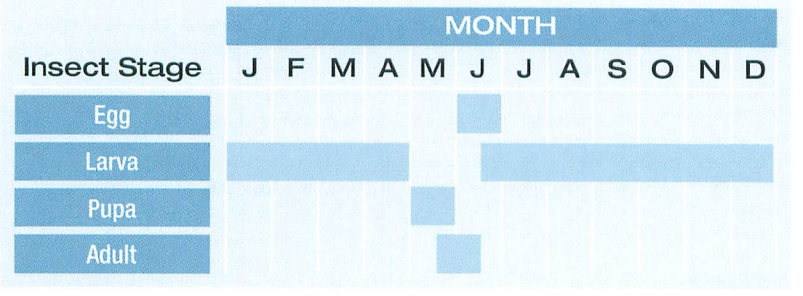
Larva and coarse frass T Arcand

TAXONOMY

Order (Family): Lepidoptera (Pyralidae)
Scientific name: *Dioryctria abietivorella* Groté
Synonym(s): *Dioryctria abietella* D et S in part
French name: Pyrale des cônes du sapin

INSECT DESCRIPTION

Egg: whitish-green, turning orange as they mature; 0.6 by 1.0 mm; oval probably laid on bark near cones
Larva: five instars; brown head and amber body that becomes darker as it matures; rows of brown spots along the back; deep amber-brown head and **prothoracic shield** when mature; 18.0-20.0 mm long when mature; develops in cone
Pupa: amber to reddish-brown; about 11.0 mm long
Adult: gray, narrow **forewing** with transverse lighter bands bordered by black; whitish-gray hind wing without marking; about 25.0 mm wingspan



HOSTS: Fir (balsam); Spruce (white, black, Norway, red); Pine (eastern white, jack, red, scotch)

DISTRIBUTION: widely distributed

DAMAGE: two to three cones held together with coarse **frass** and webbing; one or more ragged holes; extensive tunnelling inside of cone usually free of debris
IMPORTANCE: damage highly variable; up to 100% of the seed and cone crop can be destroyed
DETECTION AND MONITORING: dissect cone to find larva; also feeds under bark on twigs and main stem; no **attractant** available

CONTROL
Silvicultural: none available
Biological: none available; larvae killed by *B. t.* in lab tests
Chemical: foliar applications of systemic insecticides have been effective in reducing damage

REFERENCES
Biology: Lyons (1957a,1957c); Hard (1964); Kulhavy *et al.* (1976); Hedlin *et al.* (1981); Lindquist (1982); Brown and Amirault (1985); Churcher *et al.* (1985); de Groot (1986); Prévost *et al.* (1988); Hartling and O'Shea (1989); Trudel *et al.* (1999a,1999b)
Control: Hard (1964); Haverty *et al.* (1986); Trudel *et al.* (1997); Weslien (1999)

NOTES:

WEBBING CONEWORM

Damaged cone B Aelick

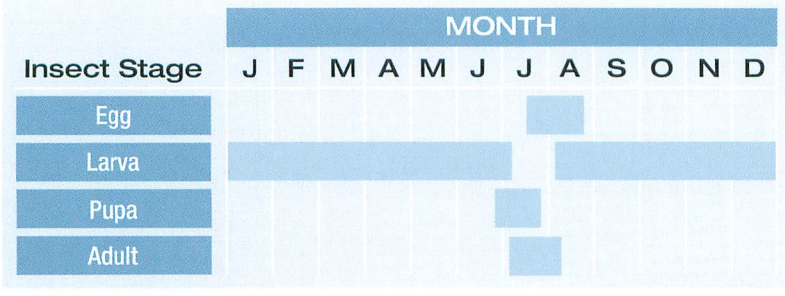
Sliced cone illustrating pupa and damage E Rayner

TAXONOMY

Order (Family): Lepidoptera (Pyralidae)
Scientific name: *Dioryctria disclusa* Heinrich
Synonym(s):
French name: Pyrale rousse des cônes du pin

INSECT DESCRIPTION

Egg: creamy white; 0.5 by 0.4 mm; oval; lightly **striated**; laid beneath bark scales
Larva: five instars; grayish-buff to olive green; first instar has eleven stripes; mature larva is 15.0-25.0 mm long; develops in cone; overwinters in **hibernaculum** beneath bark scale
Pupa: mahogany brown 9.0-14.0 mm long; rounded at the apex; heavily **sclerotized**; **caudal hooks** are lyre-shaped; found in cone
Adult: goldish-orange to reddish-brown, narrow forewing; pale smoky tan hind wing; 21.0-27.0 wingspan



HOSTS: Pine (jack, red, scotch)

DISTRIBUTION: found throughout most of eastern Canada
DAMAGE: single conspicuous hole near cone base with tightly webbed semi-coarse reddish-brown **frass** over the entrance hole; large excavation deep within seed-bearing region of cone containing dried resin, frass, and webbing
IMPORTANCE: 40-60% cone loss can occur, with complete seed loss per attacked cone: each larva probably destroys 2 cones
DETECTION AND MONITORING: dissect cone to find larva; sticky trap baited with sex **pheromone** is available

CONTROL
Silvicultural: none available
Biological: none available
Chemical: foliar applications of systemic insecticides have been effective in reducing damage

REFERENCES
Biology: Lyons (1957a,1957c); Hard (1964); Mattson (1971, 1986); Meyer *et al.* (1982); Brown and Amirault (1985); Churcher *et al.* (1985); Rauf *et al.* (1985); Weatherby *et al.* (1985); de Groot (1986); Katovich and Kulman (1987)
Control: Nord *et al.* (1984); Rush *et al.* (1987); DeBarr (1989); Fogal and Plowman (1989)

NOTES:

SPRUCE CONEWORM

Larva T Arcand

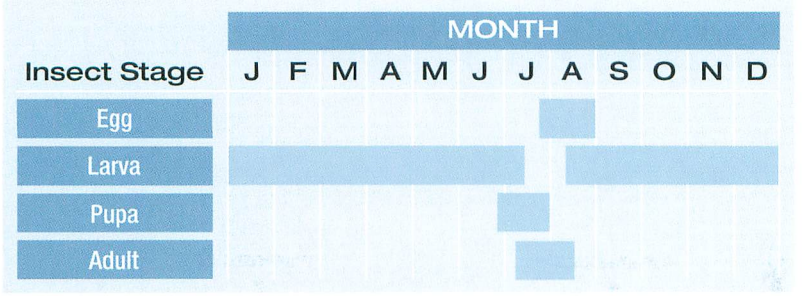
Cone with coarse frass T Arcand

TAXONOMY

Order (Family): Lepidoptera (Pyralidae)
Scientific name: *Dioryctria reniculelloides* Mutuura et Munroe
Synonym(s): *Dioryctria reniculella* Groté
French name: Pyrale des cônes de l'épinette

INSECT DESCRIPTION

Egg: creamy white; turning cinnamon brown before hatching; 1.0 by 0.7 mm; flat and **striated**; found in bark cracks and fissures of stems, and on twigs and needles
Larva: five instars; first instar is cinnamon brown with nine broken stripes; fifth instar has three cinnamon-coloured and two dark brown longitudinal stripes, a dark brown head; about 17.0 mm long when mature; develops in cone; overwinters as first instar
Pupa: dark brown; about 10.0 mm long; rounded to spined anterior projection; six even-length hooked **setae**
Adult: brownish-gray forewing with two sharp white crossbands; dark gray hind wing with pale subterminal bands and dark fringe; about 25.0 mm wingspan



HOSTS: Larch (eastern); Spruce (white, black, red); possibly Pine (jack)

DISTRIBUTION: found throughout the range of spruce
DAMAGE: first instar mines one or two needles; infested cones and surrounding shoots are enveloped in coarse **frass** and webbing; severely infested cones are usually hollowed out and all seeds are destroyed; larva often feeds under surface of cone
IMPORTANCE: up to 100% cone mortality can occur
DETECTION AND MONITORING: dissect cone to find larva; sticky trap baited with sex **pheromone** is available

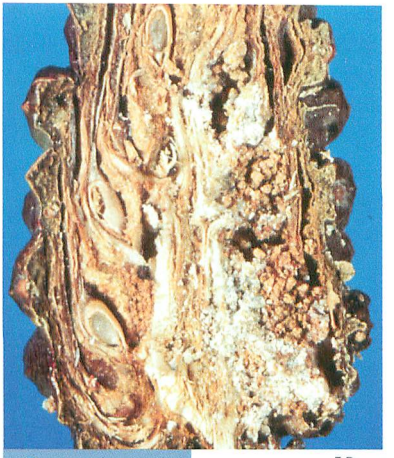
CONTROL
Silvicultural: none available
Biological: foliar application of *B.t.* has reduced populations
Chemical: foliar and soil applications, stem injections and implants, of systemic insecticides have been effective in reducing damage; generally, contact insecticides have provided little to no control

REFERENCES
Biology: MacKay (1943); McLeod and Daviault (1963); Ruth *et al.* (1980); Hedlin *et al.* (1981); Lindquist (1982); Brown and Amirault (1985); West (1985); Churcher *et al.* (1985); Grant *et al.* (1987); Prévost *et al.* (1988); Miller *et al.* (1995);
Control: Fogal and Lopushanski (1984); Brown and Amirault (1985); Churcher *et al.* (1985); Reardon *et al.* (1985); Prévost *et al.* (1988); Fogal and Plowman (1989); Hartling and O'Shea (1989)

NOTES:

RED PINE CONE BORER

Adult E Rayner



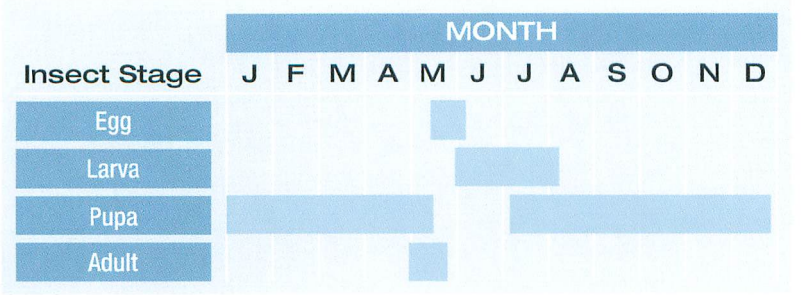
Cone infested E Rayner

TAXONOMY

Order (Family): Lepidoptera (Tortricidae)
Scientific name: *Eucosma monitorana* Heinrich
Synonym(s):
French name: Perce-cône du pin rouge

INSECT DESCRIPTION

Egg: orange; about 0.8 mm long; ovoid; laid on or near cone
Larva: five instars; grayish-white, with brown head and **pronotum**; about 12.0 mm long when mature; develops in cone
Pupa: dark brown; 7.0-8.0 mm long; found in the soil beneath tree
Adult: reddish-brown, with tan and silver markings on forewing; pale to dark gray hind wing with paler fringes; 13.0-16.0 mm wingspan



HOSTS: Pine (red and jack)

DISTRIBUTION: found throughout the range of red pine
DAMAGE: numerous small, round holes, or a few oblong holes in upper half of cone; exterior of cone almost always free of **frass**; no webbing found inside the cone; cone interior is packed with a mixture of frass and resin; extensive tunnelling in cone
IMPORTANCE: cone attack seldom exceeds 40%, but can reach up to 90%; each larva kills 1-2 cones, destroying all of the seeds
DETECTION AND MONITORING: examine cone to find egg; dissect cone to find larva; sex **pheromone** is available

CONTROL
Silvicultural: none available
Biological: none available
Chemical: soil applications of systemic insecticides have been effective in reducing damage

REFERENCES
Biology: Lyons (1957b,1957c); Barras and Norris (1967, 1969); Hedlin *et al.* (1981); Brown and Amirault (1985); Rauf *et al.* (1985); de Groot (1986); Katovich and Kulman (1987); Grant *et al.* (2002)
Control: Rush *et al.* (1987); Fogal and Plowman (1989)

NOTES:

WHITE PINE CONE BORER

Adult T Arcand

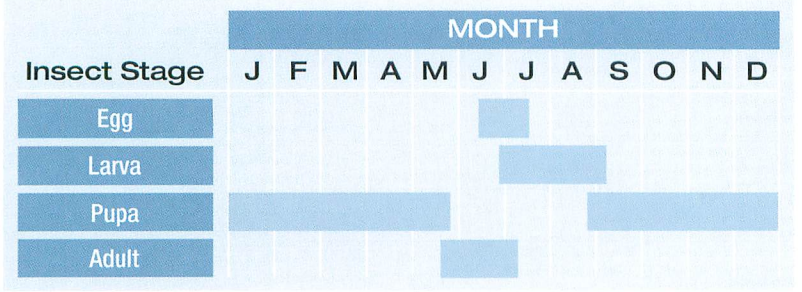
Larva near exit hole T Arcand

TAXONOMY

Order (Family): Lepidoptera (Tortricidae)
Scientific name: *Eucosma tocullionana* Heinrich
Synonym(s):
French name: Perce-cône du pin blanc

INSECT DESCRIPTION

Egg: yellow becoming orange-red; about 0.5 mm in diameter; oval to nearly circular; laid under exposed sides and tips of upturned cone scales (about 60% found in basal third of cone)
Larva: pale ivory-yellow to greenish-brown; pale **anal shield**; develops in cone
Pupa: brown; found in the soil beneath tree
Adult: distinct patches of alternating dark brown and light tan scales on **forewing**; dark brown hind wing with brownish-gray fringe; 12.0-19.0 mm wingspan



HOST: Pine (eastern white)

DISTRIBUTION: found throughout the range of eastern white pine
DAMAGE: cone peppered with many small holes and covered with patches of extruding **frass**; cone shrivels, discolours, hardens, turns brown and falls to the ground; cone interior is packed with a mixture of frass and resin as the larva feeds on scale and seed tissue, hollowing out and killing the cone
IMPORTANCE: up to 40-50% of the cone crop can be destroyed
DETECTION AND MONITORING: dissect cone to find egg and larva; sex **pheromone** is available

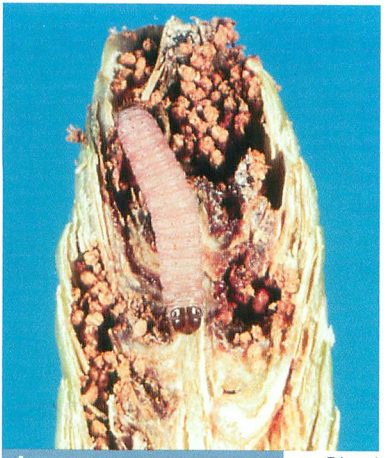
CONTROL
Silvicultural: none available
Biological: none available
Chemical: soil applications of systemic insecticides have been effective in reducing damage

REFERENCES
Biology: Ebel *et al.* (1980); Hedlin *et al.* (1981); de Groot (1998); Grant *et al.* (2002)
Control: DeBarr *et al.* (1982); Fogal and Plowman (1989)

NOTES:

SPRUCE CONE LOOPERS

Adult T Arcand



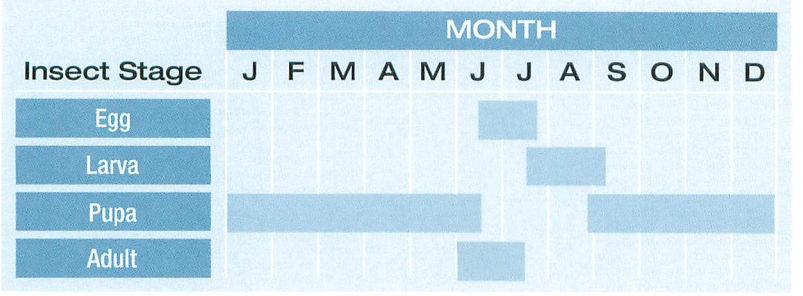
Larva in damaged cone T Arcand

TAXONOMY

Order (Family): Lepidoptera (Geometridae)
Scientific name: *Eupithecia mutata* Pearsall and *Eupithecia albicapitata* Packard
Synonym(s):
French name: petite arpenteuse des cônes de l'épinette et petite arpenteuse lignée des cônes de l'épinette

INSECT DESCRIPTION

Egg: no description available
Larva: *E. mutata* has a slender, pale pink body (without stripes) with small brown pinacula on thorax and abdomen; prominent black **prothoracic shield**; about 1.9 by 10.0 mm when fully grown; *E. albicapitata* is a stout grub-like larva with pale reddish stripes on a pale pink or brown body; about 2.5 by 10.0 mm when mature; both species have brown heads and only the 6th and 10th abdominal segments have **prolegs**
Pupa: brown for both species; overwinters in the soil



Adult: *E. mutata* and *E. albicapitata* are smoky gray with intermittent tan bands at base and tip of the wing, bordered by black and gray markings; 17.0-23.0 mm wingspan

HOSTS: Fir (balsam) Spruce (black, red, white); Hemlock (eastern)

DISTRIBUTION: found throughout the range of spruce
DAMAGE: larva leaves ragged holes on exterior of cone with small amounts of **frass** and resinous material; larva burrows and tunnels through seeds and scales
IMPORTANCE: attacks are localized with up to 20% of the cones attacked; on hemlock, one larva can destroy up to 90% of the filled seeds per cone
DETECTION AND MONITORING: dissect cone to find larva; no **attractant** available

CONTROL
Silvicultural: none available
Biological: none available
Chemical: none available

REFERENCES
Biology: MacKay (1951); McGuffin (1958); Lindquist (1982); Churcher *et al.* (1985); Turgeon *et al.* (2004)
Control: none available

NOTES:

CONE AND SEED INSECTS IN NATURAL STANDS

Introduction

Seeds are often collected from natural stands and seed collectors should take some simple steps to ensure that insects do not adversely affect the quality of the seed harvested. As a matter of good practice, it is essential that seed collectors carefully examine a selection of cones prior to full-scale collection to determine if internal damage or loss to the seeds has occurred. As indicated in earlier sections, many insects have visible signs of damage on the outside of the cone or destroy the cone completely. By the time seed collection is undertaken, most of these damaged cones either have fallen to the ground or are still attached to the tree but, because of their damaged appearance, would not be harvested. Other insects feed entirely within the cone or seed and leave little or no visible sign of damage. Failing to carefully examine a sub-sample of cones prior to harvest could result in collecting a poor quality seed lot. Such seed lots may be rejected or offered a lower price by the seed buyer. For that reason it is also critical for seed collectors to familiarise themselves with the type of damage caused by these "hidden" insects to avoid collecting damaged or destroyed seeds.

Typically, light crops following medium to heavy crops are often severely attacked by insects. Therefore it is important that crops be evaluated every year to determine potential damage. The previous year's losses do not necessarily predict this year's losses, as some insects may seem to disappear in some years only to suddenly reappear a year or two later.

Assessing cone crops and insect damage

Scouting for locations to collect seed and estimating the potential size of the crop are part of the activities of seed collectors. During these times, the seed collector should also determine the potential impact of insects on the quality, quantity and economic viability of the seed crop.

In natural stands or plantations not managed for seed production, assessments should begin on the first visit by the seed collector. If this visit is done in early to mid-June, many insects are still feeding and it is a good time to find and identify the insects. Obviously, the closer the assessments are done to harvest time the more accurate the prediction of crop size will be. Waiting until the crop is ready to harvest to begin your first assessment of the seed crop could provide some costly surprises. Time and money spent to plan seed collection can be wasted if early assessments are not carried out. Surprisingly, this is a common occurrence.

Collect a sample of about 25 cones from several trees throughout the collection site. Sample from trees that will be your crop trees (dominant to co-dominant vigorous trees)- not from isolated trees where self-pollination is likely, or from small, unhealthy trees. Do not use roadside trees exclusively because these trees often have heavier cone crops and higher pest populations. Be sure to sample from the top and bottom of the tree.

Some insects have higher population densities at the top of the tree. Thus sampling from the bottom of the tree crown, which is most accessible, will underestimate the impact. Collect cones from all sides of the tree.

Once cones have been collected, slice the sample cones in half, length-wise along their axis. Look for signs of insect damage. Count the number of full seeds per half slice, and determine from industry standards if the number of seeds per cone is acceptable. Processing cones with low numbers of seed is not economical and is likely to result in rejection of the seed lot with no financial compensation to the seed collector for their work.

CONE AND SEED INSECTS IN SEED ORCHARDS

Introduction

Seed orchards present a great opportunity for insects to feed on abundant high quality seed but also an easier and cost effective opportunity for seed orchard managers to manage insect pests and reduce their damage. Because of the high value of seed in orchards, monitoring the size and health of a cone crop over time and protection of seed crops (which should go hand-in-hand) is often done in seed orchards. Cone crop monitoring is essentially inventory control and management. Like an apple orchard producing and selling apples, seed orchards produce and sell seeds and thus to be competitive seed orchard managers must know the size of the crop (inventory) and the condition of the inventory (e.g., healthy insect-free or riddled with insects), and must have pest management methods ready to use as necessary to ensure that the final product (seeds) meets the quality standards and target levels of production.

The detection of damage in the early stages of attack should provide the manager with enough time to assess potential damage and, if warranted, to undertake control actions. Unless obligatory insects are detected at the time they initiate cone attack, or before, there is little the seed orchard manager can do to protect the seed crop that year. Pheromone or colour traps have been developed to assist the seed orchard manager in detecting the early presence of adults before they begin laying eggs.

Evaluating the size and health of a cone crop can range from informal and casual trips to the orchard through to a formal inventory system combined with methods to detect specific insects (e.g., pheromones, colour traps). Casual methods are quick,easy and inexpensive, but lack quantification that is essential to determining if pest management is justified. The benefits of formal cone crop monitoring systems are that it enables: 1) the prediction of crop size at various intervals of crop development; 2) the identification of good and poor crop trees in the orchard; 3) the quantification of cone and seed losses as well as the identification of the damaging insect(s); 4) the estimation of the efficacy of control measures; and 5) an increased ability to estimate workloads and requirements. Formal cone crop monitoring systems take time and effort to set up but the payoffs are numerous.

Its beyond the scope of this manual to describe the specific detection and monitoring systems for insects (see section 3 of this manual where references to these are provided), but what is presented here is a brief outline of the various components of a formal cone crop monitoring system and a description of one such system (ConeSys) to combine a cone crop inventory with a decision support system for pest management.

Cone Crop Monitoring

Monitoring cone crops in seed orchards involves setting up permanent sample trees with permanently tagged sample cones and examining them over the course of their development from pollination through to seed maturity for losses and the cause of loss. It also includes estimating the maximum potential of cone to produce seeds and comparing these with the actual number of seeds produced to determine the cause of seed loss in a

cone. Recall that many insects feed internally in cones without leaving external signs of damage, thus examining cones internally determines the impact of these insects.

The basic 7 steps to monitor a cone crop are as follows:

Step 1
Select trees at random from the orchard. For an average-sized orchard, the selection of 50 trees is recommended. If there is interest in specific clones or families or an area of the orchard, trees would be selected from the population of interest.

Step 2
Count all the receptive seed cones on the sample trees including those dead or damaged, and use this count to estimate the potential number of cones, seeds, and seedlings that could be produced.

Step 3
Select at random a cone-bearing branch from the sample tree, permanently mark this branch for future monitoring and record the number of cones and their condition (e.g., unattacked, attacked or dead, aborted). At least 20 cones per tree are monitored.

Step 4
Monitor the condition of the tagged cones periodically, at least 2-3 times per year, and record the number of healthy and damaged cones. Schedule the first visit when insects begin cone attack, the second, when cones are about half their mature length, and the third when cones have reached their full length. The frequency and timing of the visits is usually based on the biology of the major pests encountered in the orchard.

Step 5
After each visit, use the information to update your predictions on cone (and seed) crop size, and conduct pest management when needed.

Step 6
Collect cones when they mature.

Step 7
Extract and germinate seeds, to calculate both the actual seed potential and efficiencies in seed extraction and germination, and compare these with the predictions made at the beginning of the season.

ConeSys

ConeSys is a computer-based system designed to assist seed orchard managers in collecting and processing data on the quality and quantity of cones and seeds from their orchard, and to assist in making informed decisions about the need for insect pest management. ConeSys was developed in collaboration with many seed orchard managers in Ontario, and although the system does have a few features developed specifically for Ontario seed orchards, it is flexible enough that it can be adapted or calibrated easily for use in any seed orchard.

ConeSys consists of three core programs that function independently: The Cone Crop Monitoring System (CCMS), the Information Management System (IMS), and the Decision Support System (DSS). Both the CCMS and the IMS provide data and information for the

DSS. The CCMS provides data on the size of the cone crop and expected damage. The IMS provides information on expected damage from insect pests of pine, spruce and tamarack in eastern Canada, pest control products registered in Canada for use against these cone and seed insects, and estimates of the efficacy of the products. The DSS uses this data and asks the seed orchard manager for additional information about cost of treatment and the value of the crop to be protected to help calculate the consequences of various decisions.

Cone Crop Monitoring System. The CCMS enables seed orchard managers to estimate and predict cone and seed crop size at various times from pollination to cone maturity and harvest. It also provides estimates of the impact of insects, together with other cone- and seed-mortality factors, such as diseases, natural abortion, squirrels, and frost. The data gathered during each field visit/assessment (Steps 1-4) of the monitoring are inputted into a data logger running the CCMSDAT program. After each visit the data is downloaded to an IBM compatible personal computer (PC) where it is stored and managed (Step 5) using a program called CCMSPC. By using previous cone and seed loss data from the orchard (or some best guess when running the program for the first time), the user can either make predictions on the cone and seed yield expected at harvest or update the yield predictions. At harvest, sample cones are processed to determine seed potential, actual yield of filled seed, and seed losses.

Information Management System. The IMS is a database that provides information on the insect pests of pine, spruce and tamarack in eastern Canada. There are three main modules in the IMS program. The Diagnosis module helps identify the pest or pests causing damage to the cone and seeds on the basis of damage characteristics. Next, the system identifies the pest and the user can view or print selected information about it. The Pest module provides information on the hosts, importance and distribution of the pests, a description of the damage and life stages of the pest, and the current control methods. The Control module provides information on the pest control products registered in Canada for use against cone and seed insects. This information includes the product name, registration number, registrant and Canadian agent, location of use, market type, formulation type, precautions, first aid, environment hazards, spill cleanup, toxicology, storage and disposal instructions, directions for use, active ingredient, species of insects controlled, and estimates of the efficacy of the product.

Decision Support System. The DSS is designed to help seed orchard managers make economically and environmentally appropriate pest and crop management decisions. DSS requires seed orchard managers to input data on the current cone crop size, cost of pest management, and the expected gain in cone and seed yields from pest management, among other data. DSS processes these data and provides a cost/benefit analysis of one or more pest management options.

The complete manual can be obtained from the Canadian Forest Service, Great Lakes Forestry Centre, in Sault Ste. Marie, Ontario. Please cite:

deGroot P, Schnekenburger F, Fleming RA, Turgeon JJ 1996. User's guide to ConeSys: A Cone crop monitoring and insect pest management decision support system for seed orchards. NODA Technical Report. TR-24.102p.

GLOSSARY

abdominal segment - a subdivision of the abdomen delineated by constrictions
abiotic - non-living environmental substances and gradients
aborted - having ceased development, so as to be unfit for normal function; atrophied
anal shield - the upper part of the last abdominal segment of Lepidoptera larvae; plate-like in appearance
antennal horn - a prominent point arising from the antennae
attractant - chemical substance having positive directive response (i.e., attraction) for animals such as insects, usually in low concentration and at considerable distance
axis - of cone, the central rod-like core of a cone to which scales and bracts are attached
caudal hook - hook found at, near, or toward the tip end of the abdomen of the pupa of various lepidoptera, frequently used as a means of attachment of a pupa to substrate material
chorion - the outer shell or covering of the insect egg
cocoon - a covering, made partially or entirely of silk or other fibres, spun by a larva as a protective envelope for the pupa
conophage, -ous - insect that feeds on cone and bract tissues, usually without damaging seeds directly, although it can occur occasionally
conophyte, -ous - insect that can feed or develop only in seed cones (including seeds)
conospermatophage, -ous - insect that consumes cone and seed tissues in a clear and discriminate pattern
elytra - the chitinous wings of beetles, serving as coverings for the hindwings
endoconophyte, - ous - concophyte that spends its entire pre-imaginal development (egg, larva and pupa) within the cone or a seed
endosperm - a commonly used, but incorrect, term applied to the nutrient storage tissue surrounding the embryo in conifer seeds
exoconophyte, -ous - concophyte that exits the host as a mature larva to pupate elsewhere
forewing - the first pair of wings arising from the second thoracic segment (pages 69,79)
frass - solid larval excrement
gall - an abnormal swelling of a plant tissue
halteres - the wing balancers in Diptera, situated one on each side of the thorax and representing the hindwings
head capsule - the sutured segments or sclerites of the head which form a hard protective case
heteroconophyte, -ous - insect that feeds predominantly on foliage, shoots, twigs, cone bearing shoots and twigs and bark but that feeds or develops in seed cones when available
hibernaculum - a tent or sheath made out of foliage, or other material, in which a larva hides or hibernates
instar - the period or stage between moults in the larvae, numbered to designate the various periods; e.g., the first instar is the stage between the egg and the first moult

larva (pl. larvae) - the immature stage, between the egg and pupa, of an insect which undergoes complete metamorphosis (egg, larva, pupa, and adult)
lignification - the process by whereby plant cells become woody
mast year - a year in which, in respect of any area, there is abundant production of seed
moult - to cast off the outgrown skin when the larva or nymph changes from one instar to another
mouth hooks - cuticular claw-like structures, one on each side of the pre-oral opening; the substitute jaws of dipteran larvae
mycophagous - feeding on fungus
nymph - the immature stage of insects with an incomplete metamorphosis (e.g. Hemiptera); although similar in form to adults, nymphs have incompletely developed wings and genitalia
ovipositor - structure used to lay eggs (page 69)
oviposition - the act of depositing eggs
pedicel - a stalk or stem supporting an organ, egg or other structure
phenology - the study of the impact of climate on the seasonal occurrence of plants and animals
pheromone - a substance, secreted from a gland and released into the air by an insect, that causes a specific reaction in a receiving insect of the same species; e.g., sex pheromone
phytophagous - feeding on plants
pinaculum (pl. pinacula) - small chitinized plates on the outer covering of a larva to which body setae are attached
pitch tube - a cylinder of resin and often frass surrounding the entrance hole made by an insect
pollen cone - the male strobili of conifers which produce pollen
proleg - the fleshy, unjointed abdominal legs of lepidoptera, and of some sawfly larvae (pages 79, 80)
pronotum - the upper (dorsal) surface of the prothorax
prothoracic shield - the plate-like upper part of the prothorax, especially of lepidoptera larvae
prothorax - the first segment of the thorax of an insect bearing the first pair of legs (page 80)
pubescence - a covering of short, fine, soft, erect hair (page 35)
pupa (pl. pupae) - the resting inactive stage between the larva and the adult in insects that undergo complete metamorphosis
puparium (pl. puparia) - the thickened, hardened barrel-like larval skin of diptera within which the pupa is formed
rachis - axis of cone, central rod-like core of a cone to which scales and bracts are attached
reticulated - covered with a network of lines; meshed; netted
saprophagous - feeding on decaying matter
sclerotized - portions of insect cuticle that are hardened by substances other than chitin
seed coat - the outer coat of the seed, usually hard and brittle
seed cone - the female strobili of conifers which receive pollen and produce seeds
seta (pl. setae) - a rather short, stiff, pointed hair
spatula - a spoon or spoon-shaped unicellular process, structure, or out-growth of the body wall; the breast of a cecidomyiid larvae

spermatophage, -ous - insect that feed and develop entirely within a seed
spiracle - external opening of the tracheal system (page 42)
stigma - a short vein extending posteriorly from the marginal vein of the forewing (page 69)
striated - marked with parallel, fine, impressed lines
subterminal - below the end, or not quite attaining the end
thorax - the intermediate region of the insect body between the head and the abdomen bearing the true legs and wings (pages 35, 41, 42, 69, 79)
tubercules - a small knoblike or rounded protuberance (page 42)
univoltine - having one generation in a year

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Appendix A. INSECTS OF CONES WITHOUT A FACT SHEET

	Association[†]	Family	English common name
COLEOPTERA			
Ernobius bicolor White	?	Anobiidae	
Ernobius schedli Brown	?	Anobiidae	
Tenebroides sp.	?	Trogositidae	
DIPTERA			
Dasineura sp.	O	Cecidomyiidae	
Earomyia aquilonia McAlpine	O	Lonchaeidae	
Plemeliella sp.	O	Cecidomyiidae	
Strobilomyia abietis (Huckett)	O	Anthomyiidae	
Strobilomyia carbonaria (Ringdahl)	O	Anthomyiidae	
HEMIPTERA			
Adelges lariciatus (Patch)	?	Phylloxeridae	spruce gall adelgid
Adelges laricis Vallot	?	Phylloxeridae	pale spruce gall adelgid
Adelges piceae (Ratzeburg)	?	Phylloxeridae	balsam woolly adelgid
Mindarus abietinus Koch	?	Aphididae	balsam twig aphid
Mindarus sp.	?	Aphididae	
LEPIDOPTERA			
Acleris variana (Fernald)	F	Tortricidae	eastern blackheaded budworm
Archips packardiana (Fernald)	F	Tortricidae	spring spruce needle moth
Archips alberta (McDonnough)	F	Tortricidae	
Barbara mappana Freeman	O	Tortricidae	
Choristoneura rosaceana (Harris)	F	Tortricidae	obliquebanded leafroller
Coleophora laricella ((Hubner)	F	Coleophoridae	larch casebearer
Coleotechnites atrupictela (Dietz)	F	Gelechiidae	
Coleotechnites blastovora (McLeod)	F	Gelechiidae	
Coleotechnites laricis (Freeman)	F	Gelechiidae	orange larch tubemaker
Coleotechnites piceaella (Kraft)	F	Gelechiidae	orange spruce needleminer
Endopiza piceana (Freeman)	F	Tortricidae	
Herculia thymetusalis (Walker)	F	Pyralidae	spruce needleworm
Holcocerina immaculella (McDunnough)	F	Blastobasidae	
Hypagyrtis piniata Packard	F	Geometridae	
Spilonata ocellana (Denis and Schiffermüller)	F	Tortricidae	eye spotted budmoth
Zeiraphera canadensis Mutuura and Freeman	F	Tortricidae	spruce budmoth
Zeiraphera improbana (Walker)	F	Tortricidae	larch needleworm

[†] O, obligatory; F, facultative; ?, unknown or undetermined