The Douglas-fir tussock moth, *Orgyia pseudotsugata*, is a cyclical defoliator of Interior Douglas-fir that periodically erupts into localized outbreaks causing scattered to wider-spread tree mortality. This insect is typically first detected in very discrete patches in dry, hot, low elevation sites (350-1,250 m elevation), often on private land. Tussock moth outbreaks affect a variety of resource values. Tree growth loss and mortality reduce timber values in outbreak areas. Other values such as aesthetics, property values, and human health are adversely affected. Tussockosis, an allergic reaction to tussock moth larval setae affects some people who come in contact with the insect. Public concerns over tussock moth outbreaks are significant, as historic outbreak areas in British Columbia are located in areas where urbanization is most prevalent.

The tussock moth caterpillar and moth is covered in urticating hairs that may cause allergic reactions in people, horses and dogs. They may even stop horses from grazing pastures where there are severe outbreaks. Because of the eruptive nature of this insect, permanent trapping sites have been established in historic outbreak areas to give “early warning” of an impending outbreak. Outbreaks begin as small patches. In subsequent years, these patches may coalesce as feeding larvae disperse. After 1-5 years of defoliation, populations in a stand collapse. The collapse has primarily been attributed to a naturally occurring nuclear polyhedrosis virus (NPV). Other natural enemies, such as parasites and predators, may also play a role in the collapse of tussock moth outbreaks. The greatest percentage of tree mortality caused by tussock moth defoliation occurs during the first and second years of the outbreak cycle.

An integrated, long-term system to detect and treat tussock moth is necessary because of the dynamics of tussock moth outbreaks. Outbreaks arise suddenly in numerous patches over a broad geographic area. Damage and resultant value losses occur quickly and the outbreak then subsides. Management and avoidance of loss requires constant monitoring for increasing populations and prompt treatment of areas threatened with potentially unacceptable defoliation. An integrated management strategy has been developed and implemented in the Southern Interior Forest Region to effectively and strategically monitor, predict and treat tussock moth populations when they arise.

Pre-amble:

The strategy for managing and treating Douglas-fir tussock moth outbreaks has been updated in 2009 to reflect the addition of the biological insecticide Foray 48B, a *B.t.k.* product, to the treatment options now available for consideration. The Douglas-fir tussock moth was just added to the label of Foray 48B in the spring of 2009. This product should now be considered in the integrated pest management strategy for
management of Douglas-fir tussock moth along with the nuclear polyhedrosis virus (NPV) which is already integral to MFLNRO’s management of this insect pest.

The following updated strategy for the management of Douglas-fir tussock moth outlines when, where and why treatments may be warranted on both Crown and private lands throughout the short but eruptive outbreak cycle of this insect pest. The priorities and procedures in the strategy guide treatment programs for both Crown and private forest areas.

1. Life History and Outbreak Dynamics

The Douglas-fir tussock moth is a native insect in the low-lying, dry belt Douglas-fir regions of southern British Columbia. This insect is both a private land and public forest issue. Outbreaks of tussock moth occur every 10-12 years and cause significant damage and mortality to Douglas-fir stands in these areas. Its primary hosts are Douglas-fir, spruce and ornamental trees in urban neighbourhoods. It is a cyclic defoliator of Douglas-fir in the semi-arid portions of B.C. with patch infestations up to 250 hectares being characteristic. Trees may die after one or two years of severe defoliation and larvae are capable of killing trees in a single year if all foliage is consumed before trees can form the next year's buds. If defoliation is moderate, new buds are formed before most of the foliage is consumed and the trees may survive. The next year, however, these trees are wholly dependent on the flush from those buds, and a relatively small larval population can consume that foliage and kill the tree. Recovery of the foliage complement on defoliated trees takes several years following collapse of the tussock moth population. Larger trees may become susceptible to attack by Douglas-fir beetle, *Dendroctonus pseudotsugata*, if they have been severely defoliated.

During an outbreak, trees may be killed in one year because the Douglas-fir tussock moth feeds voraciously on both new and old needles. Defoliated trees appear reddish in colour and by July, they have taken on a scorched appearance (Fig. 1).

The tussock moth has a one-year life cycle and overwinters as eggs (Fig. 1). Adults appear from late July to early September. The adult female is flightless and remains close to her cocoon. She sends out pheromones to attract male moths. Mating and egg laying occur on the cocoon. Female tussock moths lay about 200 round white eggs. Caterpillars hatch in late spring and feed on the current year’s needles. The young caterpillars disperse by silken threads on light winds. As they mature, they feed on both old and new foliage. Mature larvae are easily identified by 3 long, black tufts: one located on the rear of the insect and two on the head.

During infestations, larvae and cocoons may be found on tree branches and trunks, fences and buildings. In an epidemic, insects may be so numerous as to be literally crawling over everything.

Tussock moths are covered in thousands of tiny hairs, which may give some people an allergic reaction, known as tussockosis. The public is advised to avoid physical contact with the insects and wash after exposure. If tussockosis symptoms are severe people should seek the advice of a physician. Individuals may find it impossible to continue working or living in or near a tussock moth outbreak. **This may warrant direct control of the tussock moth in populated rural and urban settings.**

Tussock moth outbreaks begin as localized epicentres, spreading and coalescing into large elevationally delimited areas of defoliation. The delimited pattern of defoliation is due to the
inability of adult females to disperse (vestigial wings) and dependence of 1\textsuperscript{st} and 2\textsuperscript{nd} instar larvae on windblown dispersal.

The building phase of a tussock moth outbreak takes 1-2 years. Detection of increasing insect populations during the building phase is critical, and unless detected at this stage, significant damage could occur. High population levels persist for 1-4 years, then collapse due to natural control agents which include parasites, predators (mainly birds and ants), pathogens, and starvation due to the forced consumption of older, less nutritious foliage. Collapse of the population is caused by a species-specific NPV (nucleopolyhedrosis virus) which is always present in the population at low levels. The virus is spread through insect-to-insect contact, causing population levels to crash. Six to eight years must elapse before populations reach damaging levels once again.

Population density, year in the outbreak cycle, and the current incidence of disease in the population will affect next year's damage levels. Egg sampling can be used to predict the level of defoliation for the coming year, but this level will be reduced if the outbreak is in its third or fourth year. If dead larvae are commonly found, or if egg masses are small, distorted and incompletely covered with hairs, the population is infected with virus and no significant additional defoliation will occur.

Figure 1. Description of life stages of the Douglas-fir tussock moth.

| • greyish brown spindle-shaped silken cocoon, which incorporates larval hairs | • eggs are laid on cocoons from which female moths emerge |
| • cocoons spun on foliage, branches, and boles of host trees. | • egg mass covered with body hairs and scales |

| • Larvae hatch in May-June and “balloon” from egg mass | • hairy with 4 prominent white tufts at front of body |
| • 4 to 6 instars depending on food availability | • red dots around body |
| | • long black tuft at rear, with a scattering of brown hairs |
| | • two long, black, tufts at front of insect |

| • An outbreak lasts for 2-4 years, during which serious tree mortality occurs | • female moth grey to dark brown, stout and wingless |
| | • male moth has grey-brown forewings with |
2. Long-term Management Strategies

The goal of long-term defoliation management is to reduce damage over stand rotation and in particular to reduce mid-term timber supply losses. Long-term plans are critical in areas of historic defoliator activity and potentially susceptible stands. However outbreaks will occur even with good planning. Short-term strategies then will be required to deal with these events in specific circumstances.

Long-term monitoring is necessary to provide information on population trends, changing dynamics and current and historic host ranges etc. Surveys enhance monitoring information by providing stand level site specific information, confirming identity of the defoliator estimating its population size and predicting expected impacts. Assessments quantify current levels of damage and efficacy of treatments and management strategies.

Long-term management goals and considerations include:

- Clearly defined resource management objectives;
- Economics;
- Current, historic and predicted defoliator population trends;
- Damage treatment thresholds;
- Specific values at risk;
- Operational logistics of treatment options; and
- Ecosystem impact – historical record and resource impacts.

The Douglas-fir tussock moth has an operationally calibrated pheromone monitoring system that predicts incipient outbreaks. Once the trap catches indicate an outbreak is imminent sequential egg mass surveys are initiated in susceptible stands near traps. The parameters of hazard for Douglas-fir tussock moth are listed in Table 1.

Long-term management of Douglas-fir tussock moth includes stand and ecosystem monitoring and treatments. Stand and ecosystem management includes:

- Thinning overstocked stands
- Promoting vigorous healthy trees
- Promoting mixed species where viable (e.g. Ponderosa pine and Douglas-fir)
- Targeting historic areas of tussock moth outbreaks for spacing or thinning and increasing monitoring sites in these areas
Insect population monitoring includes:

- Permanent 6-trap monitoring sites (pheromone traps in clusters of 6 in historic areas of defoliation)
- Single trap monitoring sites to augment 6-trap clusters – usually established two years prior to a projected outbreak cycle
- Review and compare each outbreak cycle in terms of extent, severity and incipient populations (start points) and adjust hazard rating or trapping sites accordingly

When trap catches increase to the critical level that an outbreak is predicted within two years, targeted ground surveys for egg masses should begin. Ground surveys should be conducted in the vicinity of the high trap catches and all susceptible forest types adjacent to these traps. Communication with local communities and residents should begin when an outbreak is anticipated. Landowners should be encouraged to place pheromone traps on their property and to look for egg masses on their trees. In this way incipient populations on private land can be located prior to defoliation occurring.

Douglas-fir tussock moth defoliation has a distinctive “signature”. In the pre-outbreak year, often single tree or very small patches of defoliation will be visible. In this year and all subsequent years of the outbreak until its collapse (3-4 years) detailed aerial surveys should be conducted. Tussock moth defoliation is difficult to accurately and thoroughly map during the Provincial Aerial Overview thus necessitating detailed surveys, particularly when western spruce budworm defoliation is occurring in overlap with the tussock moth. Particularly in years 1 and 2 detailed mapping is critical to planning treatment operations. Defoliation is often very discrete and patchy and can be easily missed in the broader scale overviews. This detailed mapping with also assist us in analysing whether the range of this insect is changing or expanding and will enable us to fine tune and improve our hazard rating maps and trapping system for future outbreaks.

Table 1. Parameters influencing hazard for Douglas-fir tussock moth.

<table>
<thead>
<tr>
<th>Stand Characteristics</th>
<th>High</th>
<th>Moderate</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogeoclimatic zone &amp; subzone</td>
<td>PP xh2</td>
<td>PP xh1</td>
<td>IDF dm1</td>
</tr>
<tr>
<td></td>
<td>IDF xh1</td>
<td></td>
<td>IDF dk1</td>
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<tr>
<td></td>
<td>IDF xh2</td>
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<td>IDF dk2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CWH</td>
</tr>
<tr>
<td>Site</td>
<td>Hot, dry</td>
<td>moderate</td>
<td>cool, wet</td>
</tr>
<tr>
<td>Species mix</td>
<td>Douglas-fir dominant or evenly distributed with Ponderosa pine</td>
<td>Ponderosa pine dominant with minor Douglas-fir mix</td>
<td>higher elevation Douglas-fir; mixed species; or non-host</td>
</tr>
</tbody>
</table>
1. **Communication and Partnerships**

Douglas-fir tussock moth typically occurs in rural and urban interface areas as well as on forested Crown land. The health risk coupled with the tree mortality caused by this insect necessitates a communication and treatment strategy by the MFLNRO and local municipalities. The communication strategy includes:

- Having information pamphlets available at local gardening and supply outlets
- Providing updated information on the Forest health web site of historic areas of outbreaks, current populations, predicted areas of concern, incipient outbreaks and links to other sources of information
- Having strategic public meetings with local communities to inform people of what the potential impacts could be and what measures they could take as landowners
- Providing lists of companies that could treat land and the available products that are effective against tussock moth and their effectiveness and mode of action
- Providing details of any treatments the MFLNRO is planning and how landowners could become included in these plans

Partnerships with Regional Districts and other local governances should be promoted so that a comprehensive plan can be developed to address the tussock moth situation. Cost sharing and information dissemination is essential to a successful treatment operation. MFLNRO staff has the operational and technical expertise whereas municipal staff have the resources for communication dissemination and land status determination.

4. **Short-term Management Strategies**

Short-term strategies employ direct methods to mitigate immediate losses from the tussock moth through foliage protection and population reduction. The choice of treatment is dependent upon the following factors:

- the values at risk (human health, private property, fire hazard, forest timber supply and other);
• the goals for area “at risk”;
• stage of the outbreak (e.g. year 1 versus year 3);
• predicted damage (defoliation);
• likelihood of success;
• operational feasibility; and,
• funding.

These direct control methods include the following:

• Chemical insecticides (e.g. Carbaryl) – not a viable option for Ministry of Forests & Range;
• Biological insecticides (e.g. NPV, B.t.k.);
• Biological control (natural parasites & predators); and,
• Mating disruption (still in research phase).

**Year 1 of outbreak cycle**

Year 1 of a Douglas-fir tussock moth outbreak is characterized by little to no visible defoliation in forested settings. Scattered clumps of less than one hectare in size may occur as a precursor to year one. Ground surveys will pin-point areas with egg masses and the concentration of these egg masses will denote the severity of defoliation to be expected in the coming year.

**Recommended treatments for year 1:**

**Crown Land:**

NPV is the treatment option recommended in year one of the outbreak cycle. This will cause the population in the area to crash with minimal tree mortality. Depending upon egg mass density, defoliation and light scattered tree mortality may still occur.

Priority areas for treatment with NPV include:

• Stands predominated by Douglas-fir
• Younger age class stands (≤ 60 years) where silviculture investments have been made (e.g. spacing, thinning)
• Mixed age forest stands containing a viable understory and intermediate age class
• Areas of high recreational use (hiking trails, recreation areas, parks)
• Woodlots
• Areas directly adjacent to private land – urban interface

Low priority sites for treatment with NPV, or “no treatment”, include:

• Douglas-fir is only a minor component of stands
• Areas of low forestry value (low density stands, minimal annual increment, poor growing sites)
• In-operable areas or areas of marginal value or use
• Areas of minimal recreational use and not in critical urban interface areas

**Private Land:**

Tussock moth outbreaks are often first observed on private land. This is due to the fact that the low elevation sites are also the most preferred for human habitation and development. Therefore
many of the highest hazard sites for tussock moth are on private land developed for farms, ranches or other development. The urticating hairs on the larvae and adults moths can cause mild to severe allergic reactions in people. In areas heavily infested with larvae, many landowners cannot even work outdoors because of the severity of their reactions. Even horses and dogs are known to have reactions to the hairs and some prime grazing leases are thus unavailable to people for grazing their horses. Coupled with the defoliation and killing of highly valued trees on private property makes control of the tussock moth a high priority. Many of the sites where tussock moth occurs is in mixtures of Ponderosa pine that has been killed by bark beetles (mountain pine beetle, western pine beetle).

Where possible, partnerships are encouraged with local Regional Districts, City councils and private citizens to develop control programs for the tussock moth.

Priority private land with incipient tussock moth (low to moderate egg mass density) that should be considered for treatment with NPV includes (MFLNRO responsibility):

- Private land adjacent to forested Crown land
- Forested Parks or recreation areas within City or Regional District Boundaries
- Private areas of woodlots

Priority private land with incipient tussock moth (high to severe egg mass density) should be considered for treatment with *B.t.k.* to quickly reduce the number of larvae and therefore the damage to trees and health hazard to people. Where possible, areas meeting the following criteria should also be treated with NPV (MFLNRO responsibility) in one of three ways, low dose, alternating swath or full dose:

- Private land adjacent to forested Crown land
- Forested Parks, playgrounds, bike or horseback riding trails, or recreation areas within City and Regional District Boundaries
- Woodlots
- Urban interface areas with mid-size, treed properties adjacent or connecting to via forested private land to Crown land

**Year 2 to collapse of outbreak cycle**

Beyond the first year of a Douglas-fir tussock moth outbreak a combination of treatments should be considered. Selection of the appropriate treatment, or combination of treatments, will depend upon:

- Land status (private, Crown, First Nations)
- Human health hazard
- Forest values at risk (mid-term timber supply)
- Severity of defoliation already incurred
- Predicted defoliation (egg mass density)
- Operational logistics (terrain, size of blocks, urbanization, funding and others)

This period of a tussock moth outbreak is characterized by larger patches of very severe defoliation and tree mortality and numerous, scattered smaller patches of tree mortality. In addition, there will be fairly extensive areas of light to moderate defoliation.
Recommended treatments for year 2 through to outbreak collapse include:

**Private Land:**

During this phase of a tussock moth outbreak, *B.t.k.* would be the treatment choice in the following scenarios:

- Existing defoliation and egg mass surveys indicate moderate to severe defoliation
- No existing defoliation but egg mass surveys indicate severe defoliation
- No existing defoliation but egg mass surveys indicate light to severe defoliation - high use area or landowners have known allergic reaction to tussock moth

The virus, *NPV*, may also be applied on select areas of private land when private land is adjacent to Crown land to ensure the collapse of the population. The virus could be applied to these areas at reduced dosage rates or in an alternate swath pattern to conserve the amount of virus used. This will enable a contagion to start while optimizing virus use.

**Crown Land:**

When severe defoliation is predicted on high value Crown land, *B.t.k.* should be considered in conjunction with NVP to minimize tree mortality. If some mortality is acceptable, *NPV* would be the treatment of choice for year 2 and year 3 if a natural collapse was not imminent.
## Timeline of activities for managing the Douglas-fir tussock moth

<table>
<thead>
<tr>
<th>Month</th>
<th>Activity description - defoliators</th>
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</table>
| **Oct-Nov** | Consultation with First Nations – plan meetings  
Determine NPV and *B.t.k.* needs for next seasons program and prepare budget |
| Jan     | Meet with First Nations  
Order supplies for spray programs (*B.t.k.*, molasses, lignosulphite and other)  
Notify landowners and communicate plans for proposed treatment  
Advertise locally about Intent to Treat |
| **Feb** | Public Information Sessions  
Advertise Aerial Spray Contract in BC Bid (if current contract expired)  
Compile, cross-check, follow-up landowner consents and spray areas  
Locate staging & mixing sites |
| Mar     | Prepare final spray block maps and distribute to landowners  
Finalize staging/mixing sites  
Prepare access notes, maps, Pesticide Treatment signs etc.  
Acquire & train contractors/staff for Wx monitoring & spray sampling |
| Apr     | Confirm Wx monitoring sites and crew designations  
Advise MOE of start-up dates, contractor information and supply maps of spray areas  
Monitor spray sites for budflush and larval hatch from eggs and dispersal |
| May     | Monitor spray sites for budflush and larval hatch from eggs and dispersal  
Weigh Virus into predetermined quantities; post Pesticide Treatment Signs  
Pre-fill mixing totes with water (evaporate chlorine) and pre-mix molasses and lignosulphite; move pre-mix solution and *B.t.k.* to staging sites |
| Jun     | Late May-early June commence spray at full egg hatch & dispersal stage (1<sup>st</sup> instar)  
Spray morning mix virus into pre-mix and apply  
Spray *B.t.k.* neat at 2<sup>nd</sup> instar stage |
| Jul     | Monitor spray program efficacy  
Field check sprayed & new areas |
<p>| Aug     | Delineate areas for fall egg mass sampling – issue contracts |</p>
<table>
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</table>
| Sep   | Early Sep detailed mapping of new tussock moth defoliation  
      | Late Sep collect all tussock moth 6-trap clusters & singlet traps  
      | Egg mass surveys  
      | Ground surveys & sequential egg mass sampling |
| Oct   | Prepare budget estimate for next fiscal year defoliator program  
      | Ground surveys and sequential egg mass sampling continue |
| Nov   | Compile survey/sampling results to mapped defoliation & priority areas  
      | Delineate potential spray blocks for treatment in next season  
      | Initiate land status of potential spray areas  
      | Update and produce new information brochures for public  
      | Order materials for spray  
      | Update Web page for posting information on outbreak status, proposed treatments, results of current years treatments and other pertinent information |
| Dec   | Start planning public information sessions  
      | Pest Management Plan – update when necessary (5 year cycle)  
      | PMP advertising and referrals  
      | Submit summary report to MOE |