

Spruce Bark Beetle

Yukon Forest Health —
Forest insect and disease

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Yukon

Energy, Mines and Resources
Forest Management Branch

Introduction

The spruce beetle, *Dendroctonus rufipennis*, is a natural disturbance agent throughout the geographical range of spruce (*Picea spp.*) in North America. At endemic levels, spruce beetle normally infest downed trees, logging debris, decked timber, dying or stressed trees and only occasionally cause tree mortality. During periods of outbreak, beetles will attack and kill live trees causing widespread mortality. In Yukon, spruce beetle is the most damaging agent of mature spruce forests. The earliest recorded outbreak occurred in the late 1930s and early 1940s around Dezadeash Lake when 50,000 ha were infested with the beetle. It is thought that logging during the building of the Haines Road contributed to this outbreak. In the mid-1970s a smaller (100 ha) outbreak occurred during the construction of the Aishihik Power Project. Both of these outbreaks were likely caused or exacerbated by human activities as trees were felled and left during construction, providing ideal breeding habitat for beetle populations.

The recent spruce beetle outbreak started in Kluane National Park and Reserve around 1990. The outbreak was first observed in 1994 by which time the beetle had already caused over 32,000 ha of mortality. The beetle then moved into public and First Nations forest lands north and south of Haines Junction in the Shakwak Trench. Over the next 15 years, the beetle continued to kill vast tracts of spruce within and west of Kluane National Park. As of 2007, more than half of the mature spruce had been killed over an area of 380,000 ha.

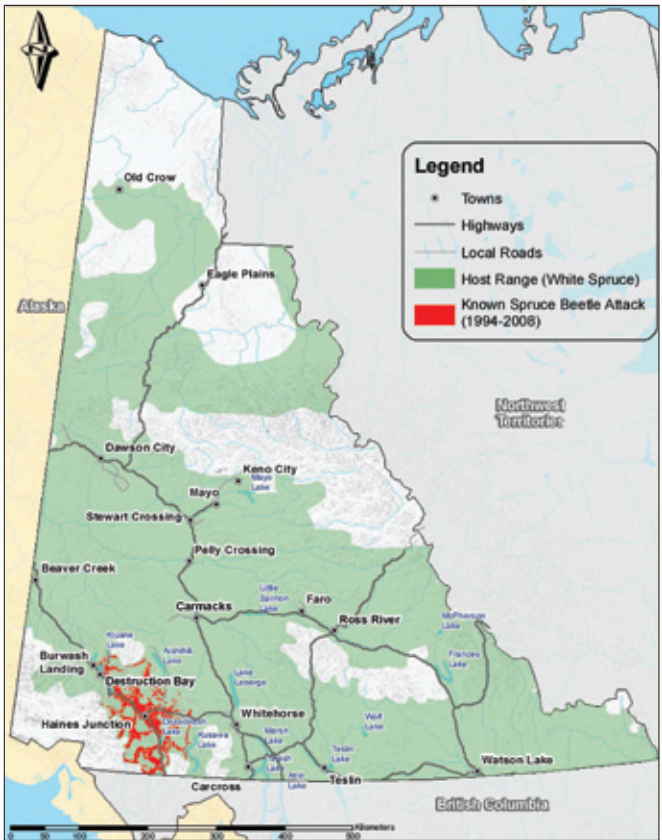
One of the main differences between the recent and historic outbreaks was the mode of initiation. In the past, outbreaks were associated with certain stand-level, abiotic disturbances such as windthrow, fire or right-of-way clearing. The recent outbreak is unique in that climate moderation was the initiation factor. Dry warm summers caused the desiccation of host trees which then became stressed and attractive to the beetles. These climatic conditions also favoured increased beetle fecundity. Over the same period, warmer winters resulted in reduced brood mortality.

Definitions:

Desiccation: *the state of extreme dryness, or the process of extreme drying.*

Fecundity: *ability to reproduce.*

Host Range for Spruce Bark Beetle



(Source data: Yukon Government Forest Inventory Data [2008] and U.S. Geological Survey [1999] Digital representation of "Atlas of United States Trees" by Elbert L. Little, Jr. (<http://esp.cr.usgs.gov/data/little/>)
Disclaimer: The data set for historic incidence is likely incomplete and only extends from 1994–2008. Endemic or outbreak populations may have occurred or may currently exist in non-mapped locations within the host range.

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Life Cycle

STAGE	Winter			Spring		Summer			Fall			W
	J	F	M	A	M	J	J	A	S	O	N	D
Egg						Late						
Larva	Overwinter (2-year cycle)						2-year cycle					
Pupa												
Adult	Overwinter			Flight Period			Late					

The life cycle of the spruce beetle typically takes one to three years depending on site position, temperature and elevation. Historically, Yukon spruce beetle populations exhibited two or three year cycling behaviour; however, in the mid-1990s and again in 2004, higher than average temperatures allowed for instances of one year cycling which greatly accelerated the spread of the infestation.

In the spring (May to July) when under-bark temperature reaches 15°C, adult flight occurs and new host material is sought out. Sometimes a second flight will occur during the late summer (July or August), especially when conditions are favourable and insects are one-year cycling.

Adults will attack new host material soon after emergence. Females bore into the sapwood and excavate the beginnings of an egg gallery. The males enter the galleries to mate with the females and then assist in the excavation. The female then packs the entrance with boring dust and commences to lay eggs in staggered batches along both sides of the egg gallery which is oriented parallel with the grain. Within two

Definitions:

Phloem: the tissue in trees that transports nutrients found just below the bark.

Instar: the stages in the growth of a larva before it pupates.

Bole: the main stem of a tree.

to four weeks eggs hatch and the larvae begin mining the phloem perpendicular to the egg gallery. In the two year cycle, early instar larvae overwinter and mature the following summer. It is at this stage that they are most vulnerable to extreme cold events. Though in the late fall they replace the water in their cells with anti-freeze and can withstand ambient temperatures of -27°C , they will usually succumb during periods of sustained -40°C or below for a week or more.

Attacking beetles carry with them a fungus that proliferates in the phloem tubes and aids the beetle in overcoming the trees defences. This fungus imbues the sapwood with a characteristic blue-grey stain.

In the late summer or early fall, brood adults may emerge from the bole and crawl to the base where they enter at the root collar to hibernate. During one-year cycling, larvae grow throughout the summer months, pupate in late summer (July/August) and overwinter as adults. Regardless of the length of the life cycle, a beetle must overwinter as an adult before it can reproduce.

Host Species Attacked and Damage

Tree species attacked in Yukon: Semi-mature to mature white spruce (*Picea glauca*). Larger trees are favoured but under intense infestations trees as small as 12 cm diameter at breast height (dbh) may be attacked.

During the first year of attack, light brown to red brown boring dust (the consistency of fine sawdust) is apparent in the bark crevices and on the ground at the base of infested trees (**photo 1**). In the years following attack, the boring dust becomes less obvious. Pitch tubes sometimes form at the entrance hole and are either white (unsuccessful attack) or brown (successful attack) (**photo 2**). However, this symptom is absent when beetles attack stressed trees or attack late in the season. Flaking bark and reddish purple trunk discoloration as a result of woodpecker damage may be a sign of infestation but is not diagnostic.

Infested trees may begin to shed green needles prior to the appearance of any visible crown symptoms. Normally between 12 and 18 months following attack the foliage of dying trees will turn yellow-orange (**photo 10**). Drought-stressed trees may begin to discolour later in the season of attack. Discolouration may vary between branches on the same tree over time (**photo 3**). Needles usually drop from the tree 14 to 20 months following attack. The exposed twigs of the upper crowns have a yellowish-orange hue and later, turn to grey (**photo 4**).

A distinguishing feature of spruce beetle damage is the gallery pattern. Main galleries are excavated parallel to the grain of the tree and average length is 13 cm. Larvae mine perpendicular to the main gallery on both sides creating a signature branching pattern. Initially, first and second instar larvae feed in a common gallery after which they radiate individually more or less perpendicular to the adult galleries.

Key features for identification:

- The oblong egg is pearly white (0.75–1.0 mm) (**photo 5**).
- Two anal shields are present on the larvae (**photo 6**).
- Pupae are creamy white during early stages and become pale tan as they mature (**photo 7**).
- The adult beetle is 4–7 mm long, cylindrical and hard bodied. The colour of the beetle changes with development from pale yellowish brown turning to red (hence the *rufipennis*) as they mature (**photo 8**).
- Main egg galleries always extend parallel to the grain from the entrance hole with smaller larval galleries protruding at right angles. Main (egg) galleries are plugged with frass (**photo 9**).

Definition:

Frass: a mixture of fecal matter and chewed plant debris.

Photo number:

- 1. Boring dust along the lower bole and root collar.**
Citation: Rod Garbutt, Canadian Forest Service.
- 2. Pitch tubes.** Citation: Rod Garbutt, Canadian Forest Service.
- 3. Tree damage.** Citation: Christian Hébert, Natural Resources Canada, Canadian Forest Service.
- 4. Stand damage.** Citation: Rod Garbutt, Canadian Forest Service.
- 5. Eggs.** Citation: Rod Garbutt, Canadian Forest Service.
- 6. Larvae.** Citation: Rod Garbutt, Canadian Forest Service.
- 7. Pupae.** Citation: Edward H. Holsten, USDA Forest Service, Bugwood.org
- 8. Adult beetle.** Citation: Scott Tunnock, USDA Forest Service, Bugwood.org
- 9. Gallery pattern.** Citation: Rod Garbutt, Canadian Forest Service.
- 10. Red/Orange attack of spruce stand.**
Citation: Rod Garbutt, Canadian Forest Service.









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Similar damage

Sapsucker damage to the lower bole and branches, frost or other stress cracks in the bark can cause resin flow and appear similar to entrance holes. Attacks by secondary bark beetles such as the northern spruce engraver beetle (*Ips perturbatus*) also produce boring dust in bark crevices; however, the *Ips* beetle boring dust is finer and often lighter in colour (due to the greater wood content). The spruce beetle larvae differ from most other *Dendroctonus* species because of the presence of two anal shields. The adult *Ips* beetle is about two-thirds the size and differs from the spruce beetle in having a rear concave depression called a declivity.

Risk Assessment

The following tables summarize the likelihood of occurrence and magnitude of impact of a pine engraver beetle outbreak at the stand level. These tables are a coarse guide for estimating the risk of an outbreak when populations are at endemic levels.

Likelihood of Occurrence

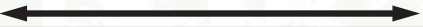
Stand Susceptibility Factor:	High 	Low
Recent stand level disturbance causing spruce mortality/debris ¹	Present (within 300 m)	Absent
Spruce composition >25 cm dbh ²	>65%	<20%
Stand health ³	Stressed/Decadent	Vigorous
Windthrow Risk ⁴	High	Low
DBH ⁵ (Diameter at Breast Height)	≥25 cm	<12.5 cm

Notes:

1. Spruce beetles are attracted to recently killed and stressed spruce or slash; therefore, nearby disturbance in spruce stands increases the likelihood of attack in adjacent spruce stands.
2. Large diameter spruce are more attractive habitat for beetles and a higher proportion of large diameter spruce increases the likelihood of attack in a stand.
3. Spruce beetles are attracted to recently killed and stressed spruce therefore stands under stress increase the likelihood of attack.
4. Spruce beetles prefer recently killed or stressed trees, thus stands with a high windthrow risk are more likely to host high beetle populations.
5. Large diameter spruce are more attractive habitat for spruce beetles.

Magnitude of Consequence

The magnitude of consequence is a subjective assessment of the potential consequences of an outbreak. This list is not exhaustive and is intended to stimulate thought on potential impacts to resource values over time.

Value	Impact							
	-				+			
Traditional Use ¹								
Comment:	Access (-)/sight-lines (-), understory flush (+)							
Visual Quality ²								
Comment:	Red/grey-attack period (-)							
Timber Productivity ³								
Comment:	Overstory (-), understory (+), firewood (+)							
Wildfire Hazard ⁴								
Comment:	Increased fuel load (-)							
Public Safety ⁵								
Comment:	Hazard trees (-), increased fuel load (-)							
Hydrology ⁶								
Comment:	Reduced water uptake (-)							
								
Time Scale (years)	20+	15	10	0-5	0-5	10	15	20+
Comment:	Impact refers to a predicted, substantial positive (+) or negative (-) impact on a value for an estimated time period							

Notes:

1. In this context, traditional use values considered are hunting, trapping and understory shrub/plant use. An understory flush (short period of increased growth due to reduced competition for light and nutrients) is assumed to lead to increased berry production and greater diversity in the understory in the short term. It is assumed that access for hunting will be more difficult due to fallen trees in the long-term. Sight lines through the stand for hunting will likely decline due to increased growth of understory vegetation, especially alder and willow.
2. Visual quality is negatively impacted initially during the red-attack period and then during the grey-attack period until the trees begin to fall and the green understory takes over.
3. Timber productivity is reduced in the long-term because the mature trees are killed and it takes many years for the understory trees to reach commercial maturity. At the same time, trees suppressed in the understory are released and their productivity increases in the short term because they are no longer competing with the overstory for resources. In the short and long term, firewood availability is increased due to the volume of standing and recently fallen dead and drying wood.
4. Wildfire hazard increases in the short term while the dead needles are retained on the spruce. It then decreases in the medium term when the needles have dropped. Hazard increases again in the long term when the dead trees fall to the forest floor and contribute large diameter fuels to the regenerating spruce fuel complex.
5. Public safety is negatively impacted in the long term by the increase in hazard trees and wildfire hazard.
6. Hydrology may be negatively impacted in watersheds in the short term if runoff is increased because large areas of mature forest are killed. Any impact would likely be short-lived as understory regeneration would make up for any significant difference in water uptake.

Implications of Climate Change

General Circulation Model (GCM) results in the 2007 Intergovernmental Panel on Climate Change (IPCC) report indicate that warming in northern Canada is likely to be greatest in winter (up to 10°C) and warmer by 3–5°C in summer. Mean annual precipitation is also predicted to increase (particularly in fall and winter). More rainfall is expected on windward slopes of the mountains in the west, therefore the rain shadow effect of the St. Elias Mountains may mean that southern Yukon will not experience increased rainfall. Higher temperatures will increase levels of evaporation and transpiration, and ultimately lower soil moisture levels. Therefore, even if summer rainfall is maintained at current average levels, higher temperatures would result in limited soil water availability and cause moisture stress in trees. Temperature and precipitation are likely to be the dominant drivers of change in insect populations, pathogen abundance and tree responses as it influences insect/pathogen development, dispersal, survival, distribution and abundance. Bark beetle species may benefit from warmer temperatures because of:

- higher rates of overwinter survival
- fewer frost events especially in early winter before larvae harden off (produce anti-freeze)
- longer summer season for growth and reproduction (shorter life-cycles)
- moisture-stressed trees with less resistance to attack

The recent spruce bark beetle outbreak has been facilitated by these factors and has resulted in extensive tree mortality. It is possible that the endemic spruce beetle population could be maintained at higher than historic levels, or that large-scale outbreaks could become more frequent over the long term, if overwinter survival and shorter life-cycles are facilitated by a consistently warmer climate. In addition, spruce beetle incidence may increase as new, climatically suitable habitats become available and by the increased frequency of drought events. However, host tissue that becomes too dry, as a result of drought, is inhospitable to spruce bark beetles. If the warmer/drier trend persists, spruce stands will become more susceptible to spruce beetle infestations up to a moisture-limited threshold.

Management Options

Monitoring

Spruce bark beetle activity can be viewed from both aerial and ground surveys. Due to the extent of the recent epidemic, this disturbance agent is best monitored through annual aerial surveys. If beetle activity is anticipated to increase then susceptible spruce stands outside of the southwest should also be monitored. The best time of year for monitoring is late summer or early fall when the foliage of last year's attack is most conspicuous. For efficiency, aerial monitoring should focus on white spruce leading stands. Ground surveys are useful where access allows the assessment of the health and vigour of the population and to determine the incidence of one-year cycling. For aerial survey standards, refer to 'B.C. Aerial Survey Standards' (MoF, 2000). For strategic planning information, refer to the Forest Management Branch risk-based monitoring strategy (Ott, 2009).

Direct Control

Direct control for spruce beetle is not generally recommended except when the population is at endemic levels or when attempting to stop an outbreak in its early stages. Options for direct control include:

- Sanitation logging is the most commonly used means of direct control. Complete timber removal of infested stands combined with prompt processing can greatly reduce the beetle population. Stumps can be either peeled or burned.
- In stands with low to moderate beetle populations, a two stage approach is used. First a sanitation cut is implemented to remove infested trees. Remnant beetle populations are removed using pheromone-baited funnel traps.

- Conventional and lethal trap trees. Conventional trap trees are healthy trees that are felled in the early spring prior to adult flight and, once infested, are removed and milled or debarked or burned. Lethal trap trees are felled, sprayed with aggregating pheromone and then treated with an insecticide. Note the spruce beetle will not attack areas exposed to direct sunlight and will only attack the underside of trap trees felled into the open. It is recommended that all trap trees be felled into shady locations.
- Pheremone trapping.

Harvesting Considerations

Harvesting of spruce may occur either as a by-product of private/industrial land clearing or if a commercial forestry operation is undertaken. The following considerations can apply to both small and large-scale tree harvesting and to either green-tree or salvage harvesting:

- Time harvesting operations to occur outside the beetle flight period and remove or dispose of logs/debris prior to the next beetle flight period.
- Minimize the amount of large diameter (>20 cm) green debris left on site in the first year after harvest. This is best implemented through pile-and-burn, broadcast burn or chipping.
- Where green debris is left, leave in full sunlight.
- Minimize windthrow hazard when designing the harvest area. Following harvest, survey windthrow in mid- to late June to determine if it is being attacked. Salvage of green windthrow in the years following harvesting will minimize host material and/or remove broods.
- Minimize stump height.
- If possible, debark logs to be decked, used for access control or other on-site purposes so that it does not provide habitat for beetles.
- Minimize site disturbance to ensure hydrology is not impacted and that residual trees are not mechanically damaged or under stress.
- When broadcast burning or burning slash piles avoid damaging the roots and boles of leave trees. This will minimize the amount of stressed trees on site and decrease the amount of suitable host material.
- Do not stack infested fire wood next to healthy trees.

Silvicultural Considerations

Silvicultural considerations are relevant post-harvest if a stand is being managed for commercial forestry or if an area is being replanted:

- Increase stand biodiversity by utilizing a range of preferred and acceptable species for planting. In southwest Yukon, this may require consideration of off-site species such as lodgepole pine (*Pinus contorta*) if ecologically appropriate.

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