

FOREST PEST MANAGEMENT

by

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Introduction

Much of the annual harvesting of timber in British Columbia (BC) is determined by insects, the most notable of which are the bark beetles that attack pines, spruces, Douglas-fir and subalpine fir. These insects compete directly with foresters for the mature trees that yield the major timber volumes as felling is directed into infested stands in an effort to utilize as much of this timber as possible. In addition, their role as natural disturbance factors leads to unplanned major changes in forested landscapes. In 2003, a major outbreak of the mountain pine beetle in lodgepole pine forests of central BC extended over more than 5.7 million hectares affecting 108 million m³ of timber worth more than \$9 billion. Some licensees presently carry out their whole annual harvesting in beetle-infested stands.

While bark beetles are the spectacular and obvious symptoms in an affected forest, the root rots and other diseases also have a serious impact on the mature forest as well as determining the options for reestablishment of the new forest. *Armillaria ostoyae* is of major significance in the southern and central parts of BC, *Phellinus weirii* in coastal BC and *Inonotus tomentosus* in the spruce dominated ecosystems of northern BC. Insects and diseases impact all aspects of our forest management from seedling establishment through to maintenance of old growth areas. Cone and seed insects and pathogens can greatly reduce seed production and in so doing greatly reduce the return on high investment, superior, genetically improved crosses. In the wood damaging category, ambrosia beetles excavate darkly stained galleries in the sapwood and thereby degrade lumber values. In high grade sawlogs, these losses are in the range of \$70 to \$80 per m³ (Orbay *et al.*, 1993). In coastal BC this represents an annual loss of \$44 million. In addition, bark and wood boring insects are important quarantine problems in export markets.

The objectives of this chapter are to provide an introduction and general overview of the topic of forest pest management in BC. Insects, diseases, abiotic factors and animal damage that affect the forest are currently termed forest health factors (FHF). In this chapter we provide concise practical summaries for certain aspects of forest health and guide you to the best available information on most forest health factor problem situations you might encounter in the field.

Federal, provincial and individual licensee responsibilities for surveying and managing forest health

The function of recording and summarizing data on the cause, location and severity of insects and disease outbreaks in BC was carried out by the Forest and Insect Disease Survey (FIDS) of the Canadian Forest Service (CFS) from 1914 through 1995. In 1980, the BC Ministry of Forests (BCMOF) established regional pest

management personnel who were responsible for translating these survey data into meaningful management strategies (McLean, 1994). In 1995, the BC Forest Practices Code (FPC) Act was enacted in BC. It was supported by a series of very useful Forest Practices Code Guidebooks on pest management issues including Bark Beetle Management, Defoliator Management, Root Disease Management and Dwarf Mistletoe Management. These guidebooks encapsulate the state of knowledge on life histories, surveys and management options for these pest groups as of 1995.

The Forest Practices Code of BC Act was consolidated in December, 2002, and a new Forest and Range Practices Act (FRPA) enacted. The regulations for this act are currently under development but will include Defined Forest Area Management guidelines that will describe licensee obligations within Timber Supply Areas. Forest Health strategies, especially issues in Beetle Management Units (BMUs), will also be closely defined.

Recent reorganization of the BCMOF has resulted in the creation of three administrative regions (Coastal, Northern Interior, and Southern Interior) as of April 1, 2003, in place of the original six (Cariboo, Kamloops, Nelson, Prince George, Prince Rupert, and Vancouver). Pest management issues will continue to be coordinated by the Forest Practices Branch which has now assumed the responsibility for providing annual overview data on the condition of the provincial forest and relating it to historical trends and projections of future losses. Licensees will be increasingly responsible for pest management activities. They are required to produce a Forest Health Strategy for their operating area that will meet the requirements outlined in the Provincial Forest Health Strategy. You will need to follow the new BCMOF organizational developments by visiting ministry web sites as the Forest and Range Practices Act regulations are formulated over the next two years (see: <http://www.for.gov.bc.ca/hfp/dfam-website/index.html>).

Forest Health Factors

The major forest health factor (FHF) groupings in BC are bark beetles, defoliators, diseases, abiotic factors and animals. In 2003, bark beetles were the major FHF (Figure 1), notably the mountain pine beetle on lodgepole pine in the northern Interior. Other significant FHF's were the western spruce budworm on Douglas-fir and pine needle cast on lodgepole pine. Data on abiotic damage and animal damage are also collected routinely.

Important commercial tree species and their occurrence in biogeoclimatic zones

As background, we list the names and symbols for commercial tree species (Table 1) and the major biogeoclimatic zones in BC including major tree species (Table 2).

Forest health factor codes

The BCMOF has developed standardized three letter codes for most FHF's to facilitate consistent recording in survey forms. An overview of these codes and specific notable examples are given in Table 3. The occurrence rating for major FHF's in each biogeoclimatic zone is provided in Table 4. Field codes are given along with common names and scientific names for each FHF.

Table 1: Names and symbols for tree species in the forests of BC.¹

Common name	Tree name Scientific name	Tree symbol	
		Genus	Species
CONIFER			
True Fir (Balsam)	<i>Abies</i>	B	
amabilis fir	<i>A. amabilis</i>		Ba
grand fir	<i>A. grandis</i>		Bg
subalpine fir	<i>A. lasiocarpa</i>		Bl
noble fir	<i>A. procera</i>		Bp
Cedar	<i>Thuja</i>	C	
western red cedar	<i>T. plicata</i>		Cw
Cypress	<i>Chamaecyparis</i>	Y	
yellow cedar	<i>C. nootkatensis</i>		Yc
Douglas-fir	<i>Pseudotsuga</i>	F	
Douglas-fir	<i>P. menziesii</i>		Fd
Hemlock	<i>Tsuga</i>	H	
mountain hemlock	<i>T. mertensiana</i>		Hm
western hemlock	<i>T. heterophylla</i>		Hw
Larch	<i>Larix</i>	L	
alpine larch	<i>L. lyallii</i>		La
tamarack	<i>L. laricina</i>		Lt
western larch	<i>L. occidentalis</i>		Lw
Pine	<i>Pinus</i>	P	
whitebark pine	<i>P. albicaulis</i>		Pa
limber pine	<i>P. flexilis</i>		Pf
jack pine	<i>P. banksiana</i>		Pj
lodgepole pine	<i>P. contorta</i>		Pl
western white pine	<i>P. monticola</i>		Pw
ponderosa (yellow) pine	<i>P. ponderosa</i>		Py
Spruce	<i>Picea</i>	S	
black spruce	<i>P. mariana</i>		Sb
Englemann spruce	<i>P. engelmannii</i>		Se
Sitka spruce	<i>P. sitchensis</i>		Ss
white spruce	<i>P. glauca</i>		Sw
hybrid spruce	<i>Picea</i> hybrids		Sx
Yew	<i>Taxus</i>	T	
western yew	<i>T. brevifolia</i>		Tw
BROAD-LEAFED TREES			
Alder	<i>Alnus</i>	D	
red alder	<i>A. rubra</i>		Dr
Arbutus	<i>Arbutus</i>	R	
arbutus ²	<i>A. menziesii</i>		Ra
Aspen, Cottonwood, or Poplar	<i>Populus</i>	A	
trembling aspen	<i>P. tremuloides</i>		At
black cottonwood	<i>P. balsamifera</i> ssp. <i>trichocarpa</i>		Act
balsam poplar	<i>P. balsamifera</i> ssp. <i>balsamifera</i>		Acb

Birch	<i>Betula</i>	E	
common paper birch	<i>B. papyrifera</i>		Ep
Dogwood	<i>Cornus</i>	G	
pacific (western flowering)	<i>C. nuttallii</i>		Gp
dogwood ²			
Maple	<i>Acer</i>	M	
bigleaf maple	<i>A. macrophyllum</i>		Mb
Oak	<i>Quercus</i>	Q	
Garry oak	<i>Q. garryana</i>		Qg
Willow²	<i>Salix</i>	W	

¹ Ministry of Sustainable Resource Management, Standards, Terrestrial Ecosystems, Vegetation. March 2003. *Forest Inventory and Monitoring Program: Growth and Yield Standards and Procedures*, Appendix 3: Species symbols - Names and symbols for tree species in B.C. Available on-line at: <http://srmwww.gov.bc.ca/risc/pubs/teveg/>

² Non-commercial species.

Table 2: Biogeoclimatic ecosystems of BC, and their most abundant tree species.¹

Biogeoclimatic ecological zone		Tree species ² present in zone, listed in order of relative abundance from dominant to less abundant
AT	Alpine Tundra	Krummholz only
BG	Bunchgrass	Mostly grasses and shrubs
BWBS	Boreal White and Black Spruce	At, Sw, Pl, Sb, Acb, Lt
CDF	Coastal Douglas-fir	Qg, Ra, Fd, Pl, Bg, Cw, Mb, Gp
CWH	Coastal Western Hemlock	Hw, Cw, Ba, Yc, Fd, Bg, Pw, Ss, Mb, Gp
ESSF	Engelmann Spruce–Subalpine Fir	Se, Bl, Pl, Pa, Pf, La
ICH	Interior Cedar–Hemlock	Hw, Cw, Fd, Lw, Pl, Pw, At, Ep, Bl, Se, Tw
IDF	Interior Douglas-fir	Fd, Py, Sw, Pl
MH	Mountain Hemlock	Hm, Ba, Yc, Hw, Cw, Fd, Pw, Pl
MS	Montaine Spruce	Sx, Pl, Bl, Fd, Lw, Cw, At, Act
PP	Ponderosa Pine	Py, Fd, At
SBPS	Sub-Boreal Pine–Spruce	Pl, Sw, Sx, Bl, Fd, Sb, Act
SBS	Sub-Boreal Spruce	Sx, Bl, Sb, Pl, Fd, At, Ep, Act
SWB	Spruce–Willow–Birch	Sw, Bl, Pl, At, W (several spp.), scrub birch (<i>Betula glandulosa</i>), Sb, Acb

¹ Based on The Biogeoclimatic Zones of BC, brochure series of 14 booklets, each individually titled “The Ecology of [one of the BGC Zones of BC]” (1996-1999, BCMOF). The brochures are accessible online, along with a map that shows the geographic distribution of each zone, at the *Growing Together Biogeoclimatic Zones of British Columbia* website: http://www.growingtogether.ca/maps/e_biogeo/biogeo.htm. See also Pojar and Meidinger (1991).

² See Table 1 for tree species symbols.

Table 3: Overview of two- or three-letter field codes used to record forest health factors on field survey forms by the BCMOF. All major categories are summarized below, along with examples¹.

Field code	Forest health factor description and example	
A	ANIMAL DAMAGE	
AC	cattle	<i>Bos taurus</i>
C	CONE AND SEED INSECTS²	
CBC	Douglas-fir cone moth	<i>Barbara colfaxiana</i>
CLO	Western conifer seed bug	<i>Leptoglossus occidentalis</i>
D	DISEASES	
DB	Broom Rust	
DBF	fir broom rust	<i>Melampsorella caryophyllacearum</i>
DD	Stem Decays	
DDE	rust-red stringy rot	<i>Echinodontium tinctorium</i>
DF	Foliage Diseases	
DFE	elytroderma disease	<i>Elytroderma deformans</i>
DL	Leader or Branch Diebacks	
DLP	phomopsis canker	<i>Phomopsis lokoyae</i>
DM	Dwarf Mistletoes	
DMF	Douglas-fir dwarf mistletoe	<i>Arceuthobium douglasii</i>
DR	Root Diseases	
DRA	armillaria root disease	<i>Armillaria ostoyae</i>
DS	Stem Disease (Canker or Rust)	
DSA	atropellis canker	<i>Atropellis piniphila</i>
I	INSECTS	
IA	Aphids or Adelgids	
IAB	balsam woolly adelgid	<i>Adelges piceae</i>
IB	Bark Beetles	
IBB	western balsam bark beetle	<i>Dryocetes confusus</i>
ID	Defoliating Insects	
IDA	black army cutworm	<i>Acetbia fennica</i>
IS	Shoot Insects	
ISB	western cedar borer	<i>Trachykele blondeli</i>
IW	Weevils	
IWC	conifer seedling weevil	<i>Steremnius carinatus</i>
M	MITE DAMAGE (TRISSETACUS SPECIES)	
N	NON-BIOLOGICAL (ABIOTIC) INJURIES	
NG	Frost	
NGK	shoot/bud frost kill	
P	CONE AND SEEDLING FUNGAL PATHOGENS²	
PSS	sirococcus tip blight	<i>Sirococcus strobilinus</i>
PDT	cedar leaf blight	<i>Didymascella thujina</i>
T	TREATMENT INJURIES	
TP	Planting	
TPM	planting-poor microsite	
V	PROBLEM VEGETATION	
VH	Herbaceous competition	

¹ Complete lists of codes (including damage agents of cones, seeds, and seedlings) are available in: Ministry of Sustainable Resource Management, Standards, Terrestrial Ecosystems. March 2003. *Forest Inventory and Monitoring Program: Growth and Yield Standards and Procedures*, Appendix 14: Damage Agents and Severity Codes.

On-line at: <http://srmwww.gov.bc.ca/risc/pubs/teveg/>

² Most codes are also tabulated in a field reference: BCMOF field card FS 747 Damage Agent and Condition Codes. 1999. BCMOF.

On-line at: http://www.for.gov.bc.ca/hfp/PUBS/forest_health/Fs747.pdf

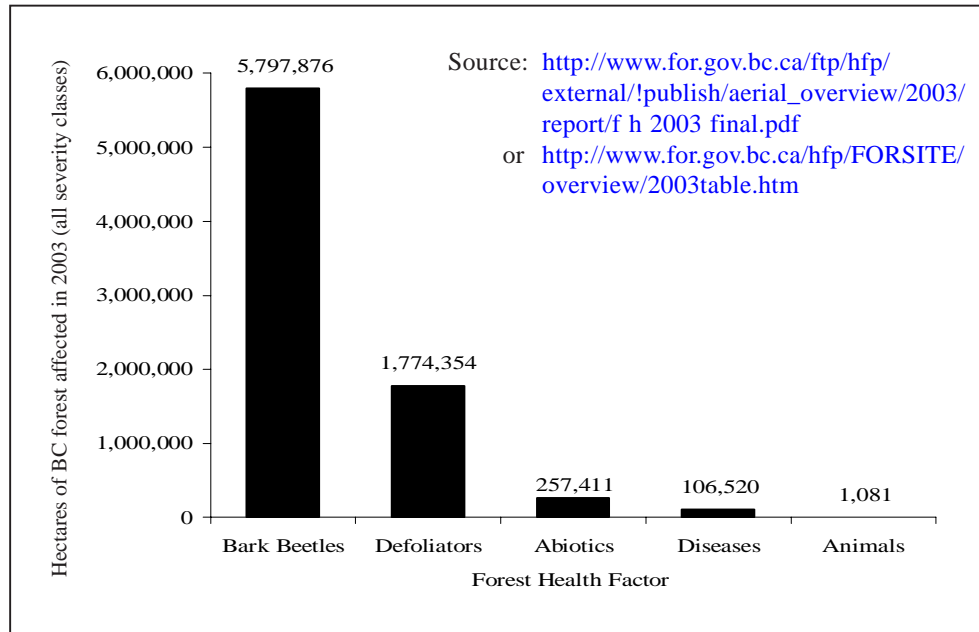


Figure 1: Major forest health factors in the forests of BC as detected by aerial surveys in 2003. The significance of tree diseases is underestimated by aerial surveys alone, as aerial surveys detect only foliage diseases, but not root diseases, dwarf mistletoes, decays and butt rots, and stem rusts.

Sources: http://www.for.gov.bc.ca/ftp/hfp/external!/publish/aerial_overview/2003/report/f h 2003 final.pdf

or: <http://www.for.gov.bc.ca/hfp/FORSITE/overview/2003table.htm>

You will have noticed in Table 3 that FHF's are listed in nine major categories: animal damage (A-), cone and seed insects (C--), diseases (D--), insects (I--), mite damage (M), non-biological (abiotic) injuries (N--), cone and seedling pathogens (P--), treatment injuries (T--) and problem vegetation (V-).

The animal damage codes are straightforward and you can see the detailed list in Table 4. Cone and seed insects and cone and seedling pathogen subcodes are based on the scientific name of the organism. For example, the Douglas-fir cone moth, *Barbara colfaxiana*, is coded C for cone and seed insect and BC based on its scientific name, for a three letter code of CBC. The sirococcus tip blight is coded P as a Cone and Seedling Pathogen and SS for *Sirococcus strobilinus* for a three letter code of PSS. The Disease FHF's (D--) are grouped by similar types. Thus broom rusts are DB- and the fir broom rust specifically is DBF. Other major disease groupings include the decays (DD-) that are saprophytic fungi that degrade

Table 4: Relative incidence of forest health factors by biogeoclimatic zone in British Columbia.

Type of damage (common name, damage agent code, scientific name)	Host(s) ^{1,2}	Occurrence in biogeoclimatic zones ^{3,4}										
		CDF	CWH	MH	ESSF	IDF	PP	SBS	SBPS	BWBS	ICH	MS
A. Insects												
balsalm woolly adelgid IAB <i>Adelges piceae</i>	Ba, Bg, B-	H	H-L									
black army cutworm IDA <i>Actebia fennica</i>	All conifer seedlings (Ba, Bl, Cw, Fd, Hw, Pl, Pw, Si, Sw, Sx)			L	M-L	L						L
conifer seedling weevil IWC <i>Steremnius carinatus</i>	B-, Cw, Fd, Hw, Ss		H-L									
Douglas-fir beetle IBD <i>Dendroctonus pseudotsugae</i>	Fd, Lw	H										H-L H-L
Douglas-fir tussock moth IDT <i>Orgyia pseudotsugata</i>	Fd, Lw, Pl											M
eastern spruce budworm IDE <i>Choristoneura fumiferana</i>	Bl, Se, Sw											H
lodgepole pine terminal weevil IWP <i>Pissodes terminalis</i>	Pl											?
mountain pine beetle IBM <i>Dendroctonus ponderosae</i>	Pa, Pl, Pw, Py		H	H-L	H-L	M-L	H-L	H-L	H-L	L		H-L H-M
pitch moth ISP <i>Petrova albicapitana</i>	Pl	H										H

Table 4 (cont'd)

Type of damage (common name, damage agent code, scientific name)	Host(s) ^{1,2}	Occurrence in biogeoclimatic zones ^{3,4}											
		CDF	CWH	MH	ESSF	IDF	PP	SBS	SBPS	BWBS	ICH	MS	
black stain root disease <i>Leptographium wageneri</i>	Fd, Pl, Pw, Py, S-	L	L			?	L					H-L	M
brown crumbly rot <i>Fomitopsis pinicola</i>	Pl; B-, Se, Sw, Ss, Pl, Pw, Py, Fd, Cw, Hw, Hm, Lw				L								
comandra blister rust <i>Cronartium comandrae</i>	Pl, Py (Alternate hosts: <i>Comandra</i> spp. or <i>Geocaulon</i> spp.)				M-L	L	H-L	M-L	M-L	M-L	H-L	H-L	H-L
Douglas-fir dwarf mistletoe <i>Arceuthobium douglasii</i>	Fd; Bg						H-L	H-M					L
hemlock dwarf mistletoe <i>Arceuthobium tsugense</i>	Hm, Hw; Ba, Bl, Plc, Ss		H-L	M									L
laminated root rot <i>Phellinus weirii</i>	High susceptibility: Ba, Bg, Fd, Hm. Moderate susceptibility: Bl, Hw, Lw, Pl, Pw, Py, Ss, Se, Si, Sx. Partially resistant: Cw	H	H-L		M-L	H-L	L	L				H-L	L
larch dwarf mistletoe <i>Arceuthobium laricis</i>	Pl, Lw; Pw, Bg						H-L	?				H-L	H-M
lodgepole pine dwarf mistletoe <i>Arceuthobium americanum</i>	Pl, Py				M-L	H-L	L	H-M	H	H	H	H-L	H-M
pine (red ring) rot <i>Phellinus pini</i>	Bl, Cw, Pl, Fd, Hw, Pw, Se, Si, Sw, Ba, Ss, Sx; P-, S-, Lw, Fd, Cw., B-, Yc, Hm		M-L	?	H-L				H-L	M	H-M	H-L	

rhizina root disease DRR <i>Rhizina undulata</i>	Bl, Bg, Cw, Fd, Hw, Lw, Pl, Pw, Py, Sx; essentially all native conifer sp. seedlings	?	L	H-L	L	H-L	H
rust-red stringy rot DDE <i>Echinodontium tinctorium</i>	Ba, Bl, Hw, Pl, Sw; B-, H-, Fd, S-, Cw	H-M	H	H	H-M	M	H-M H
schweinitzii butt rot DDS <i>Phaeolus schweinitzii</i>	Fd, Hm, Lw, Pl, Py, Sx; Hw, Ba, Bl, Ss, Sw, Lw, Lt, Pl, Pw, Cw, garry oak	L	L	H	M	M	H L
stalactiform blister rust DSS <i>Cronartium coleosporioides</i>	Pl, Py; (Alternate hosts: <i>Castilleja</i> spp., Family Scrophularaceae)	M-L	L	L	H-L	M-L	M M-L H-L
tomentosus root rot DRT <i>Inonotus tomentosus</i>	High susceptibility: Se, Si, Sw, Sx. Moderate susceptibility: Bl, Fd, Hw, Pl, Ss. Part resistant: Cw, broad-leaf sp.	L	M-L	?	H-L	M	H-L M-L H-L
western gall rust DSG <i>Endocronartium harknessii</i>	Fd, Pl, Py	M-L	H-L	H-L	H-M	H-M	H-L H-L H-L
white pine blister rust DSB <i>Cronartium ribicola</i>	Pw, Pa, Pf (Limber Pine) (Alternate hosts: most <i>Ribes</i> spp.)	?	M	M			H-M
C. Animals hare/rabbit AH <i>Lepus americanus/Sylvilagus</i> spp.	all conifer tree spp. are susceptible; Bl, Cw, Fd, Hw, Lw, Pl , Pw, Py, Se, Si, Sw, Sx	H-L	L	L	H-L	L	H H-L L

Table 4 (cont'd)

Type of damage (common name, damage agent code, scientific name)	Host(s) ^{1,2}	Occurrence in biogeoclimatic zones ^{3,4}													
		CDF	CWH	MH	ESSF	IDF	PP	SBS	SBPS	BWBS	ICH	MS			
moose AM <i>Alces alces</i>	all tree spp. are susceptible; Ba, Bl, Cw, Pl, Sw, Sx		H		H			H							
deer AD <i>Odocoileus</i> spp.	all tree spp. are susceptible; Ba, Bl, Bg, Cw, Fd, Hw, Lw, Pl, Pw, Py, Sx	H	H		L	H-L	L						H-L	H-L	
porcupine AP <i>Erethizon dorsatum</i>	Ba, Bl, Cw, Fd, Hw, Hm, Lw, Pl, Pw, Py, Ss, Sw, Sx		M-L	?	M-L	M-L	L			L			M-L	M-L	
squirrel AS <i>Tamiasciurus hudsonicus</i>	Bg, Bl, Cw, E, Fd, Hw, Lw, Pl, Pw, Py, Sx				H-L	M-L	L	H-L	L				H	H-L	M-L
cattle AC <i>Bos taurus</i>	all tree spp. are susceptible; Ba, Bl, Fd, Pl, Py														H
vole AV <i>Microtus</i> spp.	Act, Ba, Bg, Bl, Cw, Fd, Hw, Lw, Pl, Pw, Py, S, Ss, Sw, Sx		H-L		L	H-L	L	M-L	L				L	L	
D. Abiotica frost NG	All trees of all ages are susceptible; Cw, Fd					M-L	M							M	H-M
Shoot/bud frost kill NGK	Bl, Cw, Fd, Hw, (Pl), Pw, Se, Si, Sw, Sx					H-L				H-M			M-L	L	

¹ See **Table 1** for tree name symbols.

² Tree species in bold are the primary hosts, or where the most damage is present.

³ See **Table 2** for biogeoclimatic zone abbreviations.

⁴ % occurrence: **L** = Low (1 - 32%), **M** = Medium (33 - 65%), **H** = High (66 - 100%), **?** = Uncertain. Ratings in these tables were developed from "Appendix 6, Regionally Organized Provincial Forest Health Charts" in each of the six regional Forest Practices Code *Establishment to Free-Growing* Guidebooks (Cariboo, Kamloops, Nelson, Prince George, Prince Rupert, and Vancouver Forest Regions), 1995, BCMOF and Ministry of Environment, Victoria, BC.

wood through the action of their enzymes. Foliage diseases (DF-) include needle casts and blights. Leader diebacks (DL-) include the phomopsis canker (DLP). Dwarf mistletoes (DM-) are parasitic vascular plants that colonize their host and live in the bark of branches and stems as does hemlock dwarf mistletoe (DMH). Root diseases (DR-) are caused by pathogenic fungi such as *Armillaria ostoyae* (DRA) that infests the root collar. These diseases are readily vectored by insects such as the root collar weevils. Finally, there are the stem diseases including cankers or rusts (DS-) such as the western gall rust (DSG).

The insect FHF's (I--) are similarly classified into several major groupings. The first is the aphids and adelgids (IA-). These insects have sucking mouthparts that enable them to plug into the tree's vascular system, as does the balsam woolly adelgid (IAB). Bark beetles (IB-) are the most economically important group of insects, see earlier discussion on the mountain pine beetle (IBM). Here the third letter is coded often in relation to the host so that the (western) balsam bark beetle is IBB and the Douglas-fir beetle is IBF. Defoliating insects (ID-), mainly caterpillars in the order Lepidoptera (moths and butterflies) and Hymenoptera (sawflies) are coded by a unique characteristic. The eastern spruce budworm is IDE while the western spruce budworm is IDW. The black army cutworm is coded as IDA as its scientific generic name is *Actebia* (also the A in army?). The shoot infesting insects (IS-) include many different examples from several different orders. The example here is the pitch moth (ISP) *Petrova albicapitana*, on lodgepole pine. The last insect grouping is the weevils (IW-). These beetles have long snouts and are in the family Curculionidae. They inflict damage in nurseries and in young plantations when they attack around the root collar, as does the conifer seedling weevil (IWC). One of the most notorious members of this group is the white pine white pine/spruce weevil (IWS) which attacks the leaders of spruce trees throughout BC causing serious damage to tree form.

It is always important to remember that climatic conditions can also adversely affect a tree, especially late season frosts (NG-) that kill the tender tissues in expanding buds (NGK). Excessive heat, drought, sunscald, flooding, wounding, and general decline can be recorded in this category. Associating the cause with the effect which shows up much later is quite a challenge.

Some major information sources

Over the last decade a series of very useful publications have been prepared to aid in the identification of FHF's. The web based resources that you might find most useful include:

Field Guide to Forest Damage in British Columbia, 2nd Edition by J. Henigman, T. Ebata, E. Allen, J. Westfall, and A. Pollard. March 2001. BCMOF/ Canadian Forest Service Joint Publication No. 17. Victoria BC. 370 pp. Also available online at http://www.for.gov.bc.ca/hfp/forsite/pest_field_guide/index.htm. This is a very useful handbook (hereafter referred to as JP17) that has been prepared with one forest health factor per page in a ring binder format. It is printed in colour on waterproof paper. This volume is designed to be carried in the field and provides a valuable on-site resource. Hard copies can be purchased through Crown Publications at <http://www.crownpub.bc.ca/>.

On the website of the Pacific Forestry Centre of the Canadian Forestry Service there are two very useful online resources:

HForest: Hypermedia Forest Insect and Disease Knowledge Base and Diagnosis by A. Thompson, D. Shaykewich and R. Banfield. This resource is available at http://www.pfc.cfs.nrcan.gc.ca/diseases/hforest/index_e.html. Damage agent information can be assessed by way of common name or scientific name, by signs and symptoms in a problem diagnosis function, or by host tree. Adobe PDF versions of the well-respected Forest Pest Leaflet Series are also linked to by HForest.

Diseases and Insects in British Columbia Forest Seedling Nurseries by A. Thompson, J. Dennis, D. Trotter, D. Shaykewich and R. Banfield. Available at http://www.pfc.cfs.nrcan.gc.ca/diseases/nursery/index_e.html. This resource provides similar capabilities for assessing nursery insect and disease pests.

Tree Doctor by D. Corrin, N.E. Alexander, A. Speed and T. Ebata. This comprehensive guide to forest health factors was developed at Malaspina College in collaboration with the Ministry of Forests. This program is available, free of charge, from the Forest Practices Branch Training initiatives website: <http://www.for.gov.bc.ca/hfp/training.htm>. Tree Doctor is a very comprehensive undertaking that covers pest information, diagnostics, hazard and risk to the host tree at the ecological subzone level and free growing survey support. It also includes a rich series of images. Management guidelines link directly to the Forest Practices Code Guidebooks. A glossary based on *PesTerms* (Doliner and Borden, 1984) is also included.

FETCH 21 (Forest Entomology Textbook CHallenge for the 21st Century) is supported online at UBC Forestry at: <http://www.forestry.ubc.ca/fetch21/fetch21/FETCH21.html>. This site has a hypertext manual that describes the insects normally covered in the UBC undergraduate Forest Entomology course. It also includes a series of links, indexed by feeding guilds, to guide interested readers to Forest Practices Code Guidebooks and to many interesting web sites around the world.

Stand Establishment Decision Aids (SEDAs) by K. Swift, J. Turner and L. Rankin are under development by FORREX (Swift et al. 2002). SEDAs draw on many of the resources cited above, especially Tree Doctor and the FPC Guidebooks. SEDAs contain information on biological information to aid practitioners in making silvicultural decisions on site limiting factors such as competing vegetation or forest health. See <http://www.forrex.org/projects/2002/seda/homepage.asp>.

See also major texts listed in the Bibliography.

Forest Health in the New FRPA

The new policy framework being developed by the BCMOF will establish obligations and opportunities for collaborative forest management within the province's 37 Timber Supply Areas (TSA). This is termed the Defined Forest Area Management (DFAM) initiative and is designed to transfer more stewardship responsibilities from government to the volume-based tenure holders within a TSA. At this time, the responsibilities for Timber Supply Analysis and Forest Health will be obligations for replaceable forest licences and BC Timber Sales (BCTS). It is envisioned that the DFAM participants will prepare a forest health strategy according to standards and methodologies defined in the provincial forest health strategy. In addition, DFAM participants will be required to carry out detection and suppression activities in TSAs where needed to address bark beetle infestations. For further details of DFAM resources see <http://www.for.gov.bc.ca/hfp/dfam-website/resources.html>.

Annual surveys to support forest health strategies

The provincial government has the responsibility to conduct an annual aerial survey of the forests of BC and to make these data available to licensees for the development of their DFAM Forest Health Strategy. The aerial surveys are conducted from July through September by regional personnel. The results are digitized and made available to all licensees through the BCMOF website: <http://www.for.gov.bc.ca/hfp/FORSITE/overview/overview.htm>.

These overviews show the extensive problems such as bark beetle killed forests and current year defoliation. In addition to tabulation of major disturbance factors by region, there are also *Annual Summary of Forest Health Conditions in BC* reports available at this same web site. These overview surveys must be followed by detailed operational aerial surveys or ground surveys to detail the forest health factors of concern, their abundance and the actions needed at the management level. Certain forest health concerns, particularly diseases such as root diseases, rusts, cankers, decays and dwarf mistletoes are not usually visible during aerial overview surveys, and are detected during detailed ground surveys.

In developing a Defined Forest Area Management strategy in a Timber Supply Area, the following features should be examined:

- Historical occurrence of major FHF in the area – readily obtained from the FIDS Forest Health Network Archives Pest Data for BC records of the Canadian Forestry Service (in ArcInfo format) at: http://www.pfc.cfs.nrcan.gc.ca/entomology/pests/index_e.html.
- Recorded major FHF in the biogeoclimatic zones and subzones in the area, see Table 4 for a zone overview and Tree Doctor for specific subzone information. These first two items will suggest which FHF have a history of activity in your area.
- In combination with historical data and the current annual aerial survey, walk-through ground surveys should be made to verify the FHF present. Experienced foresters will know the major FHF they have to deal with through observations made across the years.
- When carrying out a walk-through survey look carefully for the symptoms that might indicate a FHF. Many of these symptoms and possible causes are summarized in Table 5. Be systematic in your examination of a tree. As you walk towards it you can assess crown foliage condition. As you come closer you will be able to see details of the current state of the branch foliage, the branch tips, the leader and the branches themselves. Careful examination of the trunk and root collar will show whether bark or wood boring insects are active. Cross check the symptoms you find with JP17 or other information sources. Fallen trees, especially recent windfalls, will also give clues about the activities of bark beetles, ambrosia beetles and wood borers (see Table 6 for more information on the latter insects).
- Specific surveys should be carried out where necessary following the guidelines laid down in the Forest Practices Code Guidebooks. These Guidebooks provide a wealth of information on the biological aspects of major significant FHF as well as the approved methods for surveys and management. You are encouraged to

Table 5: Some general symptoms and signs of damage to trees and possible causative forest health factors as seen at ground level.

PART OF TREE	Forest Health Factor		
	Observable Symptom/Sign	Insect	Disease
WHOLE CROWN FOLIAGE			
Chlorotic, thin, some needle drop, distress cones may be present; also may see sudden reduction in height increment, some trees dead or fallen	Root rot		
Thin, red/brown crown foliage, with some (current) needles green			Fungal diseases of needles: blights, casts
Needles intact but all foliage red (may also see brown boring dust on main stem, and pitch tubes or resin flow)	Bark beetles		
Top foliage striped (remaining foliage green)	Caterpillars or sawfly larvae defoliators		
BRANCH FOLIAGE			
Chewing of current foliage only	Budworm caterpillars		
Chewing of all ages of foliage	Caterpillars or sawfly larvae defoliators		
Chlorotic spots on distorted needles with white tufts; on Douglas-fir	Adelgids		
Stunted needles; on larch.	Larch casebearer		
Chlorotic spots on old foliage with yellowing; needle loss; on Sitka spruce	Green spruce aphid		
Red branch flagging; on pines			Blister rusts (cankers) (<i>Cronartium</i> spp.)

Green tip (current year foliage); with one or more bare sections with previous year(s) needles lost, or present and chlorotic/red/ brown (possibly bearing fruiting bodies/ spores); oldest needles still retained

Needle cast

Current year needles present and green; all previous year(s) needles shed, or present and chlorotic/red/ brown (possibly bearing fruiting bodies/spores)

Needle blight

Chlorosis and necrosis of needles

Drought

BRANCH TIPS

Resinosis of bud; on pines

European pine shoot moth

Flagging of branch tips; on Douglas-fir

Shoot beetle

Cone-like galling on tip; on spruces

Adelgids

Reddening of foliage buds; may also see callused patches on trunk and long vertical cracks

Frost kill

LEADERS

Dying or dead, possibly with stem deformities (crooked and or multiple leaders, crooks, forks) on lodgepole pine on spruces

Terminal weevils:

Lodgepole terminal weevil

Spruce weevil (= white pine weevil)

BRANCHES

Dense brooming (denser than dwarf mistletoes), possibly with dead branches, stem deformity, and/or growth reduction; powdery orange-yellow spores may be present on needles; needles become deciduous (are lost annually)

Rust fungi (spruce broom rust, fir broom rust)

Table 5 (cont'd.)

PART OF TREE	Forest Health Factor			
	Observable Symptom/Sign	Insect	Disease	Abiotic or Mammal
	Lion's tails; or dense brooms (denser than dwarf mistletoes), possibly with dead branches, stem deformity, and/or growth reduction; infected needles have small dark streaks (fruiting bodies); oldest needles retained		Elytroderma needle cast	
	Brooming, sometimes with swellings of branch or main stem, and/or small aerial shoots growing from host, or basal cups present after shoots shed		Dwarf mistletoes	
	Canker that is elongate, oval, sunken in centre; fruiting bodies may be present; resinosis		Branch/stem cankers e.g. <i>Dermea</i> canker	
	Woody galls on main stem or branches; spore-bearing blisters present on galls in early summer; animal feeding on older cankers followed by resinosis		Branch/stem rusts (cankers) Western gall rust (<i>Endocronartium harknessii</i>)	
	Canker; blisters bearing spores present on main stem or branches in early summer; animal feeding on older cankers; on pines		Branch/stem rusts (cankers) (<i>Cronartium</i> spp.)	
	Conk on stems, branches		Heart rot	
MAIN BOLE				
	Brown boring dust (frass); pitch tubes or resin flow; green or red foliage; on healthy living trees; on lodgepole pine	Primary bark beetles:		
		Mountain pine beetle		

on stressed living trees;
on Douglas-fir
on spruces
on subalpine fir (sometimes *amabilis* fir)
Canker that is elongate, oval, sunken in centre; fruiting bodies may be present; resinosis
Woody galls on main stem or branches; spore-bearing blisters present on galls in early summer; animal feeding on older cankers followed by resinosis
Canker; blisters bearing spores present on main stem or branches in early summer; animal feeding on older cankers; on pines
Conk on stems, branches
Bark gnawed from trees
Bark stripped from trees

Douglas-fir beetle
Spruce beetle
Western balsam bark beetle
Branch/stem cankers
e.g. *Atropellis* canker
Branch/stem rusts (cankers)
Western gall rust
(*Endocronartium harknessii*)
Branch/stem rusts (cankers)
(*Cronartium* spp.)

Heart rot
American porcupine
Black bear

FALLEN TREES/SAWLOGS

Brown boring dust (frass); pitch tubes or resin flow; green or red foliage:
on Douglas-fir (sometimes western larch)
on spruces
on subalpine fir (sometimes *amabilis* fir)
Fine white boring dust (contains both sawdust and frass); boreholes approximately 1.4 mm in diameter or smaller

Primary bark beetles (listed below) and smaller secondary bark beetles:
Douglas-fir beetle
Spruce beetle
Western balsam bark beetle
Ambrosia beetles

Table 5 (cont'd.)

PART OF TREE	Forest Health Factor			
	Observable Symptom/Sign	Insect	Disease	Abiotic or Mammal
	Coarse “shredded” white boring dust (contains both sawdust and frass); boreholes	Longhorn wood-boring beetles		
	Fruiting bodies on fallen logs		Heart rot	
ROOT COLLAR	White resinous mixture of duff around root collar	Warren’s root collar weevil		
ROOTS				
	Rotted roots or lack of laterals; fruiting bodies present ephemerally on roots, stumps, or ground, or absent		Root rot	
	Shoestring rhizomorphs and/or white mycelial fans under bark; basal resinosis; mushroom fruiting body		Armillaria root disease (<i>Armillaria ostoyae</i>)	
	Openings in mature stands; pitted, laminar decay with red-brown stain and hair-like hyphae; ectotrophic mycelium on roots in mineral soil		Laminated root rot (<i>Phellinus weirii</i>)	
	Small openings with cris-crossed windthrown trees; advanced pitted decay present in broken roots; wood remains firm; fruiting body (mushroom-like with porous underside) present in late summer		Tomentosus root rot (<i>Inonotus tomentosus</i>)	
WOOD STAINS/DECAY				
	Blue stain	Bark beetle-vectored symbiotic fungus		
	Black stain, with small bore holes and fine white boring dust	Ambrosia beetle-vectored symbiotic fungus		

Streaked black stain in sapwood	Black stain root disease (<i>Leptographium wageneri</i>)
Solid black stain in sapwood	Atropellis canker
Decayed wood is typically brown, crumbly, in small cubes	Brown rot
Decayed wood may appear white, spongy, stringy, and/or laminar; may eventually decay completely	White rot
SEEDLINGS	
Foliage chewed	Cutworms
Shoots red, bark stripped from roots or root collar	Root collar weevils, crane-fly larvae (leatherjackets)
Terminal and lateral shoots are “clipped”; girdling on root collar and roots	Rabbits/hares or voles
SEED AND CONE	
Cones turn brown prematurely and bear orange spores on scales; on spruces	Spruce cone diseases (<i>Chrysomyxa</i> spp.)
Frass on cones	Caterpillars
Galling of seed	Cone midge larvae (<i>Contarinia</i> spp.)
Abnormal seeds (as visualized by x-ray)	Seed chalcid (<i>Megasitigmus</i> spp.) leaf-footed bugs (<i>Leptoglossus occidentalis</i>)

Table 6: Characterizing features of wood damaging insects: ambrosia beetles, longhorned borers and flatheaded borers. These 3 families are all beetles (Order Coleoptera).

Wood boring beetle family	Ambrosia beetles (Scolytidae)	Longhorned (roundheaded) wood boring beetles (Cerambycidae)	Flatheaded (metallic) wood boring beetles (Buprestidae)
Economically important examples	<ul style="list-style-type: none"> - Striped ambrosia beetle <i>Trypodendron lineatum</i> - Scratch-faced ambrosia beetle <i>Gnathotrichus sulcatus</i> (Hosts: both beetles attack most conifer spp.) 	<ul style="list-style-type: none"> Sawyer beetle <i>Monochamus</i> spp. (Hosts: pines, spruces, firs, Fd) [<i>Monochamus</i> spp. vector the pine-wood nematode <i>Bursaphelenchus xylophilus</i> in the US, Japan, China and other parts of the world.] 	<ul style="list-style-type: none"> - Western red cedar borer <i>Trachykele blondeli</i> ISB (Host: Cw) - Golden buprestid <i>Buprestis aurulenta</i> (Hosts: Fd, Py) - Flatheaded fir borer <i>Melanophila drummondi</i> (Hosts: Fd, firs, spruces, Hw, Lw)
Damage	Attack dead trees, winter-felled logs left on dry land, and the upper parts of logs in booms; tunnel in sapwood; introduce black-staining “ambrosia” fungi	Bore weakened trees, windthrows, logs, dead and dying material	Bore weakened trees, windthrows, logs, dead and dying material
Distinguishing features of larva	Feed in small closed niches	Rounded thoracic region	Flattened thoracic region
Distinguishing features of adult	Feed on ambrosia fungi in main gallery	Long antennae	Flattened shape; often metallic colour
Gallery	Boring produces fine white-coloured frass at entrance hole; galleries cross grain in sapwood and fungal stain is a major agent of visual degrade	Loosely packed with fibrous frass and elliptical in cross-section	Tightly packed with frass; flattened (parallel-sided) oval in cross-section
Adult exit hole	Entrance/exit hole is circular (diameter = 1.4 mm for <i>T. lineatum</i> ; 1.2 mm for <i>G. sulcatus</i>)	Circular	Elliptical

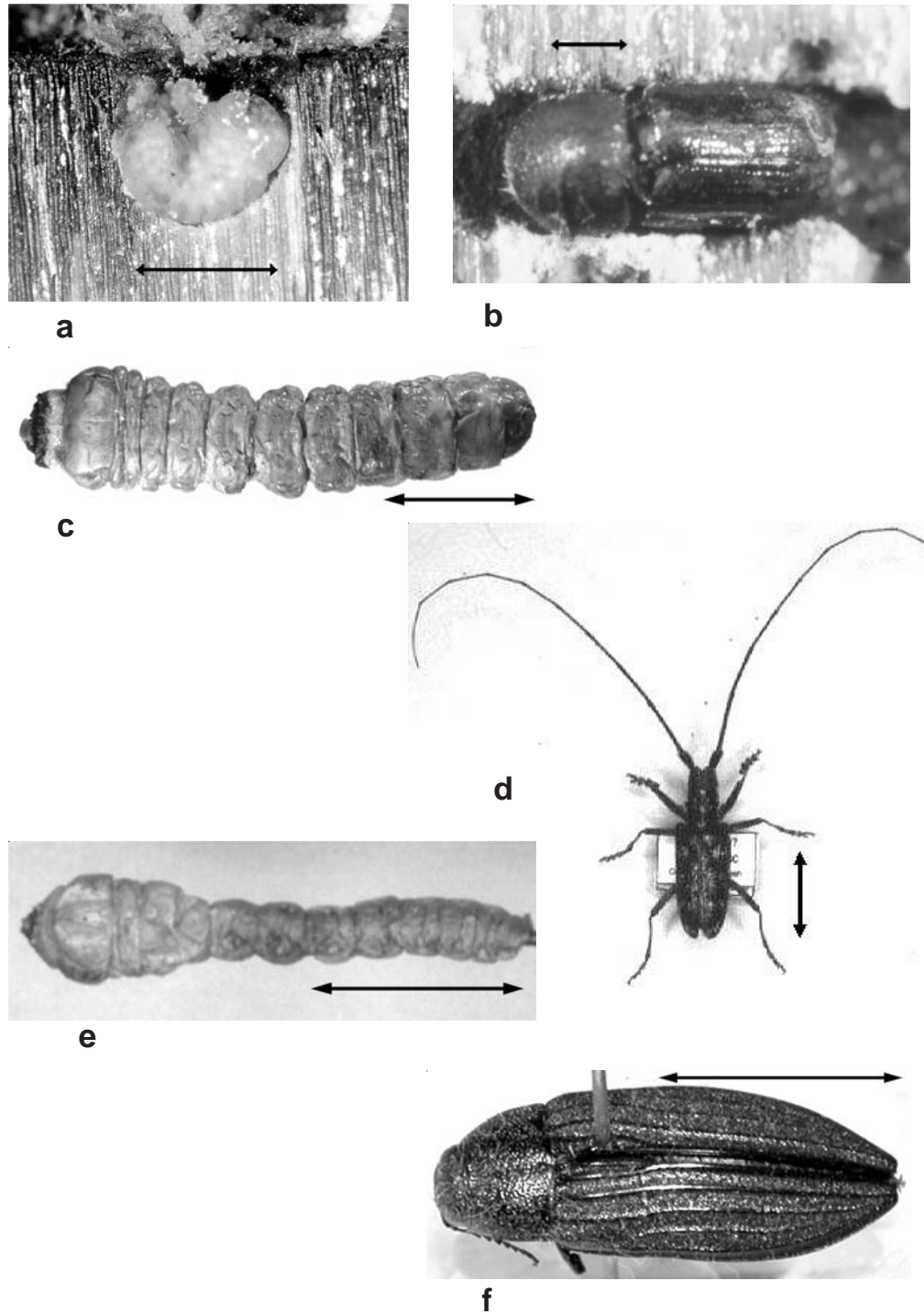


Figure 2: Wood boring beetles described in Table 6 – *Trypodendron lineatum*, an ambrosia beetle of family Scolytidae (a) larva in feeding niche and (b) adult; *Monochamus* spp., a longhorned beetle of family Cerambycidae (c) larva and (d) adult; *Buprestis aurulenta*, a flat headed wood borer of family Buprestidae (e) larva and (f) adult. For figures (a) and (b) the scale bar indicates 1 mm; for (c) – (f) the scale bar indicates 1 cm.

utilize these materials as you develop your management plans. All the FPC Guidebooks are indexed at:

<http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/guidetoc.htm>.

Those of particular interest with respect to Forest Health are:

Surveys	<i>Generic Forest Health Surveys</i> , Second Edition (2001)
Insects	<i>Bark Beetle Management</i> (1995) <i>Defoliator Management</i> (1995) <i>Management of Terminal Weevils in BC</i> (1996)
Plant Pathogens	<i>Dwarf Mistletoe Management</i> (1995) <i>Pine Stem Rust Management</i> (1996) <i>Root Disease Management</i> (1995) <i>Tree Wounding and Decay</i> (1997)

Bark beetle management

The major bark beetles, the mountain pine beetle (IBM), spruce beetle (IBS) and Douglas-fir beetle (IBF) have a significant impact on forestry activities in BC as they kill mature trees. In several areas of BC, a major part of the volume cut is taken from bark beetle infested forests in an attempt to reduce bark beetle populations and utilize the attacked trees before the wood deteriorates on the stump.

Each bark beetle has specific management options that integrate with its life history. IBF and IBS overwinter as adults and emerge in spring. This means that winter-felled trees as well as blow down and snow/ice break trees are vulnerable to attack. All merchantable material should be transported to a sawmill before spring breakup. IBM over winters in the larval stage and does not emerge until late June or early July. Spring sampling determines the degree of over wintering mortality and forewarns summer population levels. A provincial bark beetle strategy has recently been published by the BCMOF to address the current serious forest health issues these beetles create at: <http://www.for.gov.bc.ca/hfp/FORSITE/fhdata/ProvBBStrategy.pdf>. The strategy is based on the fundamental elements of the bark beetle-host interactions that are fully described in the FPC Bark Beetle Management Guidebook (<http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/beetle/betletoc.htm>).

Young stands are relatively immune from successful bark beetle attack but as the stands age, especially after about 80 years (16-20 cm diameter) their phloem is thick enough to support a successful bark beetle attack. Preventive management recognizes that older trees are more susceptible so that there is a need to plan timely harvesting of these most susceptible stands. Hazard rating systems relate tree and site characteristics to attack success by beetles. Over time, large expanses of even-aged forests can be converted to a mosaic of age classes and tree species. It is also possible to space lodgepole pine stands to 4 m or 5 m spacing so that trees retain sufficient vigour to successfully ward off an IBM attack. Such stand manipulation needs to be incorporated into forest health strategic plans.

There are various ways to directly control beetle populations. While they are at low levels, spots of newly attacked trees can be harvested, felled and burned or injected with MSMA. When spots amalgamate into patches then pheromone baits can be used to attract beetles into a stand during the summer so long as the whole stand is harvested over the winter and the infested trees transported to a mill for manufacture. When a very large area of mature forest is infested by beetles, the only option is to salvage log the better quality stands and utilize the fibre before it

deteriorates on the stump. In isolated areas, it may not be possible to carry out any management at all and these trees will deteriorate and natural stand succession will take place.

The key elements of bark beetle management (listed in the Provincial Bark Beetle Strategy) are:

- Rating stands for susceptibility and risk of depletion
- Annual detection surveys and mapping of infestations
- Annual assessments of rates of change in infestation levels and spread
- Prompt, appropriate and thorough action on all infestations where suppression or control to some degree is feasible.

All management plans need to allow for this potentially serious impact on planning objectives and to ensure continued management actions protect investment both in the local licence area and in adjacent jurisdictions.

Use of pesticides

There are occasions when you might need to intervene directly by using a pesticide. All pesticides must be used in a manner that meets federal and provincial regulations, especially the BC Pesticide Control Act and its regulations (available at: http://www.qp.gov.bc.ca/statreg/reg/P/319_81.htm#section%2028).

All pesticides must be used only as indicated on the label of the pesticide container, both by method of application as well as only for listed approved target organisms. If your target FHF is not listed on the label then that product cannot be used. People planning to use a pesticide on public lands need to have a Pesticide Use Permit or have an approved Pest Management Plan. Pesticide Use Permits are issued by the Ministry of Water, Lands, Air and Parks. The person carrying out the application needs to have a Pesticide Applicator's Certificate.

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- Forest Pest Leaflet Series. Pacific Forestry Centre, Canadian Forest Service, Natural Resources Canada/ Forestry Canada. Forest Pest Leaflets are a series of about eighty short but detailed publications dealing with important insects,

tree diseases, and other forest health factors. PDF versions of most of the FPLs are available online, at:

1. HForest (under “Species by: Common Name” or “Scientific Name”):
http://www.pfc.cfs.nrcan.gc.ca/diseases/hforest/index_e.html.
2. the PFC online bookstore (select the “search” option, then enter “Forest Pest” into the “series and volume” field):
<http://bookstore.pfc.forestry.ca/index.htm>.

Forest Practices Code. Establishment to Free Growing Guidebooks. BCMOF version 2.3 of Cariboo Forest Region (2002), or versions 2.2 of Kamloops, Nelson, Prince George, Prince Rupert, or Vancouver Forest Regions (2000), are available for download at:

<http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/guidetoc.htm>.

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Additional internet resources:

BC Ministry of Forests

- Forest Practices Branch – Home: <http://www.for.gov.bc.ca/hfp/hfp.htm>
- Forest Practices Branch – Silviculture Practices Section – Forest Health Unit: http://www.for.gov.bc.ca/hfp/FORSITE/forest_health.htm
- Forest Range and Practices Act: <http://www.for.gov.bc.ca/code/>
- Legislation & Regulations pertaining to forestry: <http://www.for.gov.bc.ca/tasb/legsregs/comptoc.htm>

General

- A listing of Forest Pathology related websites: http://www.umaine.edu/fes/Classes/int256/home/web_sites.htm
- USDA Forest Service- Forest Health Protection website: <http://www.fs.fed.us/foresthealth/>
- USDA Forest Service Pacific Northwest Region Office: <http://www.fs.fed.us/r6/nr/fid/>

Glossary

The following are common or important forest health terms that may have been used in this chapter or that are useful to be aware of. For a full glossary of Forest Health terminology (PesTerms) see Doliner and Borden (1984).

Abiotic Non-living.

Basal resinosis (pitching) Large exudations of pitch at the base of the stem at or below the root collar, often associated with *Armillaria* root disease or Warren's root collar weevil. See also **resinosis**.

Broom/brooming In woody plants, an abnormal shortening of internodes (the region of stem between any two nodes, the places where leaves attach) and proliferation of weak shoots, forming a dense brush-like mass (also called a **witches' broom**). Commonly induced by dwarf mistletoes, rust fungi, or other organisms, but sometimes a response to abiotic stresses. Mistletoe brooms are evergreen, while needles of brooms induced by rusts generally last only one year.

Canker A localized, well-delineated area of diseased tissue in bark and cambium of main root, stem, or branch, often with an overgrowth of surrounding tissues as a result of reaction of the host plant to infection.

Chlorosis Yellowing of normally green tissue, due to destruction or reduced production of chlorophyll, often a symptom of some metabolic deficiency, disease, feeding by sucking insects, root or stem girdling, or extremely reduced light. A distinction is sometimes drawn between **chlorosis** and lack of colour due to growth under insufficient light (**etiolation**).

Crook A defect in trees or logs, consisting of an abrupt bend, that can result from insect-induced topkill and recovery by a lateral branch. A minor crook is called a **crease**. See also **fork**, **shepherd's crook**, and **staghead**.

Damage The physical and ecological effects of a forest health factor on tree or forest growth, structure, productivity, and/or use.

Decay The decomposition of wood caused by fungi, resulting in softening, progressive loss of strength and weight, and often changes in texture and color. See also **laminar decay** and **rot**.

Dieback The gradual and progressive dying, starting at the tips, of shoots, twigs, tops, branches or roots.

Duff The organic litter layer of the forest floor comprised of organic debris such as leaf litter, bark fragments, twigs, etc. in varying states of decomposition.

Flagging A conspicuous, red or chlorotic branch in a green crown.

Fork A major defect resulting when two laterals assume dominance, possibly caused by loss of a leader or apical shoot due to terminal weevils. See also **crook**, **shepherd's crook**, and **staghead**.

Frass Solid excrement of insects, particularly larvae; that of wood-eating insects such as bark beetles can be called **borings dust**.

Frequency The number of repetitions of a periodic process (e.g. defoliator outbreak) in a period of time (e.g., in a 25-year period). A relatively high frequency would be an outbreak every decade.

Fungal anatomical structures:

Conk The shelf-like or flat spore-producing structure of some wood decay fungi, particularly heart rot fungi; forms on the external surface of its host; seen on tree trunks, branches or stumps.

Ectotrophic mycelium A mass of white or gray mycelium found on the outside surface of roots; the mycelium may be covered by a dark brown crust if it has been exposed to the air. Ectotrophic mycelium facilitates the initial spread of *Phellinus weirii* from root to root. See also **mycelium**.

Fruiting body Fungal structures that contain or bear spores, such as mushrooms and **conks**.

Hypha (plural hyphae) A microscopic, fine, thread-like, often branched structure formed of fungal cells.

Mycelial fans Fan-shaped mass of hyphae, formed between bark layers or between bark and wood of trees. Often found near the base of trees infected with *Armillaria* root rot.

Mycelial sheet A felt of hyphae, in other than a fan-shaped pattern, formed in cracks in decayed wood, or between bark layers or between bark and wood of trees.

Mycelium A mass of vegetative, interwoven hyphae, usually considered as distinct from the fruiting body. See also **ectotrophic mycelium**.

Rhizomorph A root-like strand composed of hyphae, often much branched, occurring in certain fungi, e.g. *Armillaria*.

Gallery A passage, burrow, tunnel or mine excavated by an insect (especially by bark beetles) in plant tissues for feeding, oviposition, or shelter. Bark beetle galleries are constructed in the inner bark and often may etch the surface of the wood. Their general pattern is characteristic for particular genera and even for certain species.

Galls/galling A localized proliferation of greatly modified plant tissue, induced by another organism such as an insect or disease fungus, that results in a pronounced permanent swelling, lump, or abnormal outgrowth of malformed bark or woody material. Commonly has a characteristic shape, often spherical, unlike any organ of the normal plant.

Girdling The destruction of the conducting bark tissues (phloem) all the way around a trunk, stem, branch or root, preventing the movement of photosynthetic products and causing the affected plant part to die. When the trunk is girdled,

nutrient depletion may cause the roots to die, cutting off the water supply to the crown, thus killing the top as well. Many deciduous trees once girdled can repair the damage and survive. Girdling may be caused by bark beetles, weevils, rodent gnawing, or fungal infections.

Gouting Excessive swelling of a branch or shoot, often accompanied by misshapen needles and buds; frequently caused by balsam woolly adelgid on true firs.

Incidence The proportion or percentage or frequency of occurrences of a given phenomenon, such as a disease or insect infestation, in a defined sampling unit (normally a plot or a stand). To avoid confusion when using incidence, always indicate the sampling entity and sampling unit.

Laminar decay Decayed wood separating readily along growth rings (= delamination), characteristic of infection by *Phellinus weirii*.

Lion's tail The isolated tuft of current needles remaining on branches or branchlets after all the other needles have been cast as the result of a severe foliage disease.

Necrosis The death or disintegration of cells or tissues while they are still part of a living organism; in plants usually resulting in a darkening of the affected tissue.

Parasite An organism that lives part or all of its life cycle in (**endoparasite**) or on (**ectoparasite**) a different organism, the host, and from which it derives part or all of its sustenance. See also **parasitoid**.

Parasitoid A parasite, typically an endoparasitic fly larva or wasp larva, that ultimately kills its host, often by consuming most or all of its internal tissues. See also **parasite**.

Pathogen Organisms (usually very small or microscopic) such as bacteria, fungi, protozoa, helminths, viruses, or viroids, that cause or induce disease in their host.

Pitch tube A mass of resin and often frass or boring dust at the point of entry of an insect (often a bark beetle) into bark, cones etc. of various conifers, as a result of the severing of resin ducts by the boring activity of the insect.

Primary bark beetles A bark beetle that is the first to arrive at, utilize, complete development in, and/or kill an apparently healthy, living tree. See also **secondary bark beetles**.

Resinosis Flow of resin or pitch in a conifer, in response to infection, wounding or insect (often bark beetle) attack. See also **basal resinosis**.

Root collar The part of a tree where the main roots join the trunk, usually at or near ground level.

Rot A state of (usually advanced and obvious) decay caused by fungi. The word **rot** also refers to or is part of the name of a disease characterized by this symptom. See also **decay**.

Saprophyte An organism that commonly feeds on dead organic material, usually by decomposing and absorbing it, and assisting in its decay. Saphrophytes, in

certain circumstances, may attack living hosts (e.g. those weakened by primary pathogens or stress) and become pathogens.

Secondary bark beetles A bark beetle that attacks trees that are already weakened, dying or dead as a result of a primary insect (often a primary bark beetle) or pathogen.

Shepherd's crook A leader or branch with a down-curved tip in the shape of a shepherd's crook, characteristic of attack by certain insects (especially terminal weevils on spruces) or pathogens (for example, Fusarium root rot in Douglas-fir seedlings). See also **crook, fork, and staghead**.

Sign Objective evidence, such as the visible portion of a pathogen, or its products, seen on or in the host. Compare with **symptom**.

Staghead Three or more laterals assuming dominance; a major defect often resulting from terminal weevil attack. See also **crook, fork, and shepherd's crook**.

Symptom A phenomena, or circumstance observed or detected in the host that is associated with, or a known reaction to, disease, infection, injury, or attack. Compare with **sign**.