Extension Note

BC Journal of Ecosystems and Management

Southern Interior Forest Region

Forest Health Stand Establishment Decision Aids

Art Stock[1], Marnie Duthie-Holt[2], Sheri Walsh[3], Jennifer Turner[4], and Kathie Swift[5]

Introduction

Since 1998, the Early Stand Dynamics program of FORREX–Forest Research Extension Partnership, in collaboration with its volunteers and partners, has assessed the information needs of the operational silvicultural community. This process identified a number of issues relating to management of competing vegetation, forest health, silvicultural systems, and best practices. Besides information needs, members of the silvicultural community also expressed concern about the loss of their experiential knowledge.

These operational concerns prompted the initiation of an extension project to fill in identified information gaps and document local knowledge. Competing vegetation and forest health were selected as the first subject areas on which to focus effort. Information relating to these two subject areas was collected, synthesized, and presented in an easy-to-use format. The resulting product was then presented to both the operational and scientific communities for review and input.

The extension product generated by this process was called a "Stand Establishment Decision Aid" (SEDA). SEDAs are designed to provide information on the biological features that new and inexperienced practitioners need to consider when making silvicultural decisions about site limiting factors such as competing vegetation or forest health. These decision aids are not intended to make the decisions for practitioners.

The first forest health SEDAs published in the *BC Journal of Ecosystems and Management* were developed for the former Cariboo Forest Region before it, and the Nelson and Kamloops forest regions, amalgamated into the Southern Interior Forest Region. Readers interested in this previously published information can obtain parts 1 and 2 at: ***www.forrex.org/jem/2002/vol2/no1/art1_rev1.pdf*** and ***www.forrex.org/jem/2002/vol2/no2/art4_rev1.pdf***

The nine SEDAs presented in the current article focus on forest health concerns found within the Southern Interior Forest Region as a whole. Some of these SEDAs discuss insects or pathogens that were already addressed in parts 1 and 2 for the Cariboo Forest Region. Consequently, these particular SEDAs only provide information for the former Kamloops and Nelson forest regions.

Each SEDA provides a hazard rating system that identifies the specific biogeoclimatic zone and subzone where the forest health problem potentially occurs, a detailed description of the characteristics of susceptible stands, and some general information on the insect's or pathogen's biology. In addition, harvest and silviculture strategies to consider when managing susceptible stands are presented, as well as the potential productivity implications of infestations. Each SEDA concludes with a resource section outlining where more information can be located.

Acknowledgements

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KEYWORDS: *black army cutworm, black stain root disease, comandra blister rust, forest health, harvesting, insects, pathogens, rhizina root disease, silviculture, Southern Interior Forest Region, spruce weevil, western gall rust, western hemlock looper, western spruce budworm, white pine blister rust.*

Contact Information

1 Entomologist, Art Stock Consulting Ltd., 515–4th Street, Nelson, BC V1L 2S4. Email: artstock@telus.net
2 Entomologist, Medifor Forest Health Consulting, 2715–8th Street South, Cranbrook, BC V1C 4N1. Email: medifor@telus.net
3 Silviculturalist, Sheri Walsh and Associates, 4318 Poplar Ridge, Crescent Valley, BC V0G 1H0. Email: sjwalsh@telus.net
4 Extensionist–Ecosystem Productivity, FORREX–Forest Research Extension Partnership, c/o Malcolm Knapp Research Forest, 14500 Silver Valley Road, Maple Ridge, BC V4R 2R3. Email: jennifer.turner@forrex.org
5 Early Stand Dynamics Specialist, FORREX–Forest Research Extension Partnership, 360–1855 Kirschner Road, Kelowna, BC V1Y 4N7. Email: kathie.swift@forrex.org

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Black Army Cutworm – Southern Interior Forest Region

Black army cutworm larvae.

Characteristics of Susceptible Stands

- Drier sites
- New plantations established on recent burns with little other vegetation

General Information

- Season of the fire determines population development of the cutworm, and when damage can be expected.
- On sites burned in May to July, defoliation occurs in the spring following the fire.
- On sites burned in late August to October, defoliation occurs in the second spring following the fire.

Major Life Cycle Events

- From July to October, adult moths fly; they lay eggs in loose sandy soil or ash.
- Eggs hatch in about 2 months; the small larvae overwinter in the soil.
- From May to June, noticeable defoliation occurs with late-stage larvae.
- Caterpillars pupate 3–7 cm into loose soil; adults begin to emerge in July.

Hazard Rating

BEC Zone[a]	Drier subzones	Wetter subzones
ESSF	dk[b]: High hazard; dc1[b,c,d]: High hazard (?)	wc1[b,c,d]: High hazard (?); wc2[b,c,d]: High hazard; wm[b,c,d]: High hazard (?); vc[b,c,d]: High hazard (?)
ICH	xw[d]: Mod–high hazard (?); dw[d]: Mod–high hazard (?)	mk1+2[b]: High hazard; mk3[f]: Moderate hazard; mw1+2: Mod–high hazard (?); mw3[b]: High hazard; wk1: Mod–high hazard (?); wk2+4[f]: Mod–high hazard; vk1: Mod–high hazard (?)
IDF	dm1[e]: High hazard (?)	
MS	dm1[e]: Moderate hazard (?); dk[c]: High hazard	

Hazard Rating Key

Speculated hazard (limited or conflicting data)	Low hazard	Low–mod hazard	Moderate hazard	Mod–high hazard	High hazard
?	blue dotted	cyan vertical stripes	green horizontal stripes	orange diagonal stripes	solid red

[a] See Meidinger and Pojar (1991) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.
[b] Maher (1990).
[c] Personal communication: Emile Begin, former Forest Health Officer, Invermere Forest District, B.C. Ministry of Forests, Invermere, B.C.
[d] Braumandl and Curran (1992).
[e] Lloyd *et al.* (1990).
[f] Personal communication: Leo Rankin, Forest Entomologist, Southern Interior Forest Region, B.C. Ministry of Forests, Kamloops, B.C.

Hosts: Spruce species, lodgepole pine, western larch, Douglas-fir, and trembling aspen

Silviculture Considerations

- The post-harvest hazard is highest when the site is burned in the spring and no herbaceous food source is available.

Regeneration and Establishment

- To assess risk of seedling damage, a protocol that uses pheromone-baited traps is available for monitoring moth densities.
- For blocks burned in the spring (May–June) of the previous year, delay planting until most cutworms have pupated (i.e., mid-July). This allows seedlings 1 year to establish before being subjected to attack; sites also gain an additional summer to "green-up" and provide cutworms with alternative (and generally preferred) food sources.
- If cutworm damage is expected when seedlings are planted, the simplest and safest approach is to plant on moist sites as early as possible in the spring (which should strongly limit seedling damage); on sites where significant moisture stress is expected, delay planting for 1 year.
- Plant fall-burned sites immediately; closely monitor spring-burned sites.

Potential Effects on Productivity

- Expect relatively low levels of seedling mortality (15%) under normal moisture conditions with good planting quality.
- Cutworm damage is synergistic with adverse seedling condition (i.e., associated with poor site or planting quality, or drought); up to 40% seedling mortality occurs under these conditions.
- Seedling mortality will be greater if stock is planted during defoliation phase than if defoliation phase occurs 1 year after planting.
- Most mortality occurs among those seedlings that are more than 60% defoliated, especially if buds are destroyed. Douglas-fir is highly susceptible to cutworm damage. Spruce will suffer significant mortality if defoliation exceeds 60%. Lodgepole pine is relatively resistant to damage.

Black Army Cutworm – Southern Interior Forest Region

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Black Stain Root Disease – Southern Interior Forest Region

B.C. Ministry of Forests

Evidence of black stain root disease.

Characteristics of Susceptible Stands

- 15–60-year-old, intensively managed Douglas-fir stands; however, Douglas-fir mortality from black stain root disease declines after about age 25
- 45–100-year-old lodgepole pine stands; stands above 1000 m and older than 80 years are very prone to infection

General Information

- Limited knowledge exists about the distribution of black stain root disease across BEC zones.
- This disease is often associated with other root diseases such as *Armillaria*.
- Black stain is a vascular wilt disease, not a root decay disease.
- Disease does not persist in pine stumps, or in Douglas-fir stumps after spacing.
- Suspected to persist in old-growth Douglas-fir stumps, and to subsequently infect residual or newly planted stems, but this is less well understood.
- Predisposed or injured Douglas-fir trees growing in disturbed areas, such as road sides, land-fills, and especially where stumps are created, show susceptibility to local and long-distance disease spread via root-feeding beetles (*Hylastes nigrinus*) and weevils (*Steremnius carinatus* and *Pissodes* spp.); however, healthy Douglas-fir and lodgepole pine have also been attacked.
- Secondary disease spread can occur through root grafts or close contact between roots of diseased and healthy trees.
- Black stain root disease in the Southern Interior occurs in distinct centres, but also as small, less noticeable pockets of mortality scattered throughout stands.
- For lodgepole pine, tree mortality may be attributed to mountain pine beetle or *Ips* spp., which are often found in diseased trees.

Hazard Rating

BEC Zone[a]	Species[b]	Drier subzones	Wetter subzones
ESSF	Pl[c,d]	xc[c] (? low); dc1[c] (high); dc2[c] (low); dv[c] (? low)	mw[c] (? low); wc2[c] (? low)
ICH	Pl[c,d]		mk1[c] (moderate); mk2[c] (? low); mw2+3[c] (low)
ICH	Fd[c,e]		mk1+2[c] (? low); mw2+3[c] (? moderate); wk1[c] (? low); vk1 (? low)
IDF	Pl[c,d]	dk1+2[c] (low); dm1[c] (moderate)	mw1+2[c] (low)
IDF	Fd[c,e]	xh1+2[c] (low); dk1+2[c] (moderate); dm1[c] (low)	mw1+2[c] (? low)
MS	Pl[c,d]	xk[c] (moderate); dm1+2[c] (moderate); dc[c] (moderate)	
MS	Fd[c,e]	xk[c] (? low); dm1+2[c] (? low); dc[c] (? low)	
PP	Fd[c,e]	xh1+2[c] (? low); dh1+2[e] (moderate)	

Hazard Rating Key

Speculated hazard (limited or conflicting data)	Low hazard	Low–mod hazard	Moderate hazard	Mod–high hazard	High hazard
?					

[a] See Meidinger and Pojar (1991) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.
[b] Fd = Douglas-fir, Pl = lodgepole pine.
[c] Lloyd *et al.* (1990).
[d] T.F. Braumandl and M.P. Curran (1992) consider that black stain root disease generally occurs throughout the range of lodgepole pine in southeast British Columbia.
[e] T.F. Braumandl and M.P. Curran (1992) consider that black stain root disease generally occurs on Douglas-fir throughout the ICH and IDF zones in southeast British Columbia.

Hosts: Lodgepole pine and Douglas-fir; minor hosts include western and mountain hemlock, spruce species, and white pines

Harvest Considerations

- Minimize site disturbance. Pre-plan skid trails and falling direction. Clean up and remove damaged trees during road building. Avoid road building through young (< 30-year-old) stands.
- Minimize tree injury. Avoid creating flooded areas, or damaging young stands. Avoid using rotary-blade brush cutters to clear roadsides.

Silviculture Considerations

- No direct controls exist for black stain root disease; recommended management activities are primarily preventative.

Regeneration and Establishment

- Plant species mixtures.

Plantation Maintenance

- Plan pre-commercial thinning for late June to early September; this minimizes the suitability of slash for build-up of vector populations by avoiding vector flight periods and allowing slash to dry out.
- Favour less susceptible tree species during pre-commercial thinning. Leave infection centres unthinned, and leave an unthinned 8–10 m buffer zone around infection centres.

Potential Effects on Productivity

- Disease centres and number of trees killed can be substantial for both Douglas-fir and lodgepole pine stands.
- As many as 30 Douglas-fir have been killed in patches (disease centres); some pine stands incurred infection rates in excess of 50% over areas as large as 350 ha.
- Direct mortality may occur as a result of infection; attacks by bark beetles may contribute to the demise of infected trees.

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Comandra Blister Rust – Southern Interior Forest Region

U.S. Department of Agriculture Forest Service

Damage from comandra blister rust.

Characteristics of Susceptible Stands

- Pine stands 5–30 years old, although it will attack pines of all sizes and ages

General Information

- Comandra blister rust is an obligate parasite on living plants, with a complicated life cycle that alternates between two different hosts.
- This parasite grows as a perennial in the inner bark of hard (lodgepole or ponderosa) pines, and as an annual on the stems and leaves of herbaceous hosts (e.g., bastard toad-flax or false toad-flax).
- Because of variations in the distribution of the alternate host and the periodicity of environmental conditions necessary for infection, disease outbreaks are sporadic.
- This disease favours high humidity and moisture. Epidemics occur after slow, moist warm fronts pass during late summer; however, outbreaks are generally localized.

Major Life Cycle Events

- The "aecial" hosts are 2- and 3-needle hard pines (more than 30 species, including lodgepole and ponderosa pine). From April to May, aecia develop into bright orange blisters from which aeciospores disperse. Aeciospores are released during dry, warm, windy weather, remain viable for long distances, and can infect herbaceous hosts several kilometres from the nearest infected pine tree.
- After production of aeciospores, infected pine bark cracks and dries out, resulting in death of the bark and sapwood.
- The "telial" hosts are perennial herbs such as comandra, or bastard toad-flax (*Comandra umbellata*), and false toad-flax (*Geocaulon lividum*). These hosts produce basidiospores that disperse relatively short distances and germinate on pines during periods of high humidity.
- Symptoms develop on pines 3–5 years after initial infection.
- Combinations of wind pattern, spore dispersal events, and local and landscape humidity levels produce sporadic "waves" of infection on pines. The prevalence of the alternate host determines the local infection source. Many stands escape serious damage, but some do not. It is impossible to predict which stands will be seriously affected.
- Plantations may provide a good microclimate for this disease; for example, a relatively humid environment is produced if branches are low to the ground. Comandra blister rust attacks pines of all sizes and ages, although young pine (i.e., 5–30 years old) are highly susceptible. If a "wave" year of infection occurs during the early years of stand development, infection rates will be high. After stands gain height, individual tree susceptibility appears to decrease. Most stem infections occur within 1 m of the ground and often begin as branch infections.

Hazard Rating[1]

BEC Zone[a]	Drier subzones				Wetter subzones			
ESSF	xc[c]: Low ?	dc1[b,c,d]: Mod–high ?	dc2[c,d]: Mod–high ?	dv[c]: Low	wm[b,c]: Low	wc1[b]: Low	wc2[c]: Low	wc4[b]: Low
ICH	xw[b]: Moderate	dw[b]: Moderate			mk1[b,c,d]: Mod–high ?	mk2[c]: Low	mw1[b]: Moderate	mw2+3[b,c]: Low–mod ?
IDF	un[b]: Low	dk1+2[c,d]: Mod–high ?	dm1[b,c,d]: Mod–high ?	dm2[b]: Moderate	mw1+2[c]: Low			
MS	dc[c,d]: Mod–high ?	dm1+2[b,c,d]: Mod–high ?	dk[b]: Moderate	xk[c,d]: Mod–high ?				

Hazard Rating Key

Speculated hazard (limited or conflicting data)	Low hazard	Low–mod hazard	Moderate hazard	Mod–high hazard	High hazard
?					

[a] See Meidinger and Pojar (1991) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.
[b] Braumandl and Curran (1992).
[c] Lloyd *et al.* (1990).
[d] B.C. Ministry of Forests and B.C. Ministry of Environment (1996).

[1] The hazard table includes information only for those biogeoclimatic subzones found in the former Kamloops or Nelson forest regions. For information on subzones in the former Cariboo Forest Region, see Swift *et al.* 2002.

Hosts: Lodgepole and ponderosa pines

Harvest Considerations

- Harvest heavily infected stands, leaving only non-infected seed trees.
- Monitor trees for evidence of cankers, blisters, and swollen branches. Once this disease enters the trunk, no effective control is possible.

Silviculture Considerations

- Eradicating the alternate host is not practical.

Regeneration and Establishment

- Occurrence of susceptible genotypes is important. A pine species will show wide variation in susceptibility to rust fungi. Planting provenances outside of the areas in which they evolved can disrupt existing rust-resistance mechanisms.
- Regenerate previously infested stands with non-host tree species, or select resistant pines if possible.
- Increase stocking density to offset rust-caused mortality. Denser stands appear to have less incidence of comandra blister rust; denser stands reduce the occurrence of alternate hosts and increase the self-pruning of lower branches.

Plantation Maintenance

- Maintain vigorous growth by properly watering, fertilizing, and mulching crop trees.
- Remove infected merchantable trees with lower- to mid-crown cankers.
- If possible, space in late spring during aeciospore dispersal (most visible) to maximize disease removal; however, ensure that control efforts themselves do not spread the disease.
- Spacing young stands without regard for rust incidence will increase rust incidence in stands, and may reduce healthy (or live) stems per hectare below acceptable levels.
- Prune and dispose of infected branches (within 22 cm of the stem) on high-value trees.

BIOLOGICAL CONTROL

- Research indicates that the purple mould, *Tuberculina maxima*, may be useful as a biological control agent. This mould restricts aeciospore production.

Comandra Blister Rust – Southern Interior Forest Region

Potential Effects on Productivity

- During outbreaks, comandra blister rust causes growth reduction, stem deformities, fewer cones and seeds, and mortality.
- The number of years it takes comandra blister rust to girdle the main stem equals twice its diameter (in inches) at the spot where the canker occurs. Most infections begin on branches and spread at a rate of 2.5 cm/year. If the branch dies before the fungus reaches the trunk, the fungus also dies. Therefore, the farther a branch infection is from the stem, the less chance that the fungus will reach the main stem, form a canker, and kill the tree.
- Most stem cankers are lethal.
- Squirrels commonly feed on cankers and may hasten host mortality.

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Rhizina Root Disease – Southern Interior Forest Region

B.C. Ministry of Forests

Rhizina root disease damage and fungal growth.

Characteristics of Susceptible Stands

- Newly established plantations burned within 2 years before planting.

General Information

- *Rhizina* is activated by fires in areas with acidic soils in which live conifer roots are present and spores occur in the duff.
- Within susceptible subzones, rate burned sites at risk by the previous or current presence of western hemlock and by the intensity of the fire. Moderate-intensity fires provide the best environments for *Rhizina* to grow; these fires sterilize the soil and eliminate more aggressive saprophytic fungi that would otherwise out-compete *Rhizina*.
- Intense burns that scorch and dry the duff will destroy *Rhizina*.
- Light burns in which the duff remains intact allow other fungi to remain active, thereby reducing the incidence of *Rhizina*.
- *Rhizina* root disease does not attack mixed species stands or broadleaved species.
- Fruiting usually occurs in moist areas, approximately corresponding to Interior Cedar–Hemlock biogeoclimatic subzones, and to some extent on sites transitional between Montane Spruce and Interior Douglas-fir moist warm and moist cool subzones (although no systematic assessment has been made). Occurrence has been noted in the Engelmann Spruce–Subalpine Fir zone near Cranbrook in southeastern British Columbia.
- Fruiting bodies are dull chestnut-brown to black, with a tough flesh and undulating upper surface. The undersurface is yellowish to ochre with numerous branched, root-like rhizoids.
- The fruiting bodies appear between May and November; in wet years, however, they most commonly appear in late summer and fall. Fruiting bodies develop at least 15 weeks after a burn and can release spores throughout the growing season.
- About 2.5 years after burns, fruiting bodies become rare and seedling mortality ceases.

Hazard Rating

BEC Zone[a]	Drier subzones	Wetter subzones
ESSF	dc1[b]: Low ?; dk[b]: Low ?	wc1+2[b]: Low ?; wc4[b]: Low ?; wm[b]: Low ?; vc[b]: Low ?
ICH	xw: Low; dw: Low–mod; mk1[b]: Moderate; mw1[b]: Mod–high	mw2+3[b]: High; wk1[d]: Mod–high; vk1[c]: Low
IDF	mw[e]: Low–mod; mk[e]: Low–mod	
MS	mk[b]: Moderate ?; mw[e]: Low–mod	
SBS	dw1+2[f]: ?	mc1+2[f,g]: ?; mh[f,g]: ?; mm[f,g]: ?; mw[f,g]: ?; wk1[f,g]: ?

Hazard Rating Key

Speculated hazard (limited or conflicting data)	Low hazard	Low–mod hazard	Moderate hazard	Mod–high hazard	High hazard
?					

[a] See Meidinger and Pojar (1991) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.
[b] Norris (1989).
[c] Lloyd *et al.* (1990).
[d] Garbutt (1988).
[e] Personal communication: Hadrian Merler, Regional Pathologist, Southern Interior Forest Region, B.C. Ministry of Forests, Kamloops, B.C.
[f] Personal communication: Richard Reich, Regional Pathologist, Northern Interior Forest Region, B.C. Ministry of Forests, Prince George, B.C.
[g] Rhizina may become an issue for burned, wetter Sub-boreal Spruce subzones, particularly those that are transitional to the Interior Cedar–Hemlock biogeoclimatic zone.

Hosts: Western redcedar, Douglas-fir, pines, spruces, western larch, western hemlock, and true firs

Silviculture Considerations

- No direct controls exist.
- To determine where planting can occur, conduct a pre-planting survey of fruiting bodies, burn intensity, and fireweed growth on areas burned within the last 10–16 months.

Regeneration and Establishment

- Immediate replanting is possible in regions such as the dry Interior where fruiting of *Rhizina* is sporadic, or on areas that have experienced a severe fire.
- Plant in areas where fireweed is doing well (may require some brush control); avoid areas that have experienced "moderate" burns or where fruiting bodies are present. Otherwise, delay planting at least 1 year (preferably 2 years in susceptible wetter subzones), or consider fill-planting after *Rhizina*-caused mortality subsides.
- To avoid future *Rhizina* damage in localized areas that were previously severely affected, pile and burn slash, and either do not plant in the burned areas, or delay planting for 1–2 years after burning.

Potential Effects on Productivity

- Damage is sometimes extensive and significant.
- Seedling mortality of up to 34% has been observed; however, mortality is generally expected to average 25% on one-half of the apparently susceptible blocks.

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Spruce/White Pine Weevil – Southern Interior Forest Region

B.C. Ministry of Forests

Spruce weevil damage.

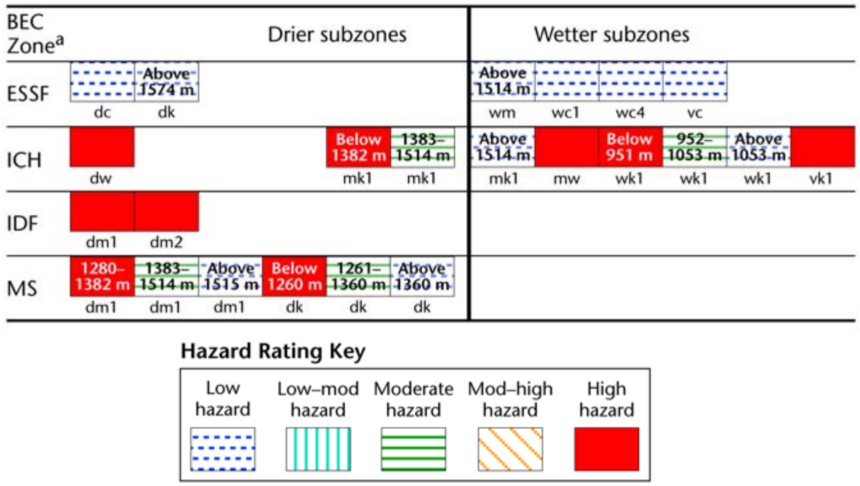
Characteristics of Susceptible Stands

- Warmer sites; high-hazard sites generally accumulate at least 800 degree days of heat over 7.2°C, and medium-hazard sites receive 720–800 degree days; weevil development is not possible with less than 720 degree days
- Open, fast-growing stands
- Spruce weevils (also known as white pine weevils) prefer open-growing, fully sunlit trees from 0.5 to 12 m in height, and with terminal diameters of 5 mm or more
- Plantations in which adjacent stands were heavily attacked

General Information

- Over 46 000 ha of susceptible spruce plantations exist in southeast British Columbia.
- An Integrated Pest Management system for spruce weevil should include hazard rating, silvicultural control, use of genetic resistance, and direct control.

Hazard Rating[1]



[a] See Meidinger and Pojar (1991) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.

[1] Pinnell *et al.* (1995). The hazard table includes information only for those biogeoclimatic subzones found in the former Kamloops or Nelson forest regions. For information on subzones in the former Cariboo Forest Region, see Swift *et al.* 2002.

Major Life Cycle Events

- Spruce weevils cycle through one generation per year.
- Adults overwinter in the duff, crawling or flying to host trees from late April to mid-July.
- Both males and females feed in the bark just below the terminal bud cluster of the previous year's leader; this causes resin beads to ooze from small (0.5–1.0 mm) punctures.
- Eggs are laid in cavities in the bark, just below the terminal bud cluster extending down the upper half of the terminal shoot.
- Egg cavities are capped with a dark brown excrement to seal off and protect the eggs. Eggs hatch within 6–14 days.
- Larval survival is often determined by competition for food; however, when only a few eggs occur, larvae may drown in pitch, which deforms but does not kill terminal shoots.
- Larvae form a "feeding ring," burrowing down the leader, first in the inner bark and then between the wood and bark. After 5–6 weeks, larvae construct pupal cells in the pith and wood of the stem. Small strands of wood lining create a chip cocoon, which characterizes pupal cells.
- From late July to early September, newly developed adults chew small round emergence holes through the chip cocoon and bark.
- Wilting of the terminal leader and laterals forms the characteristics "shepherd's crook."

Hosts: Spruce species

Harvest Considerations

- When harvesting or implementing alternative silvicultural systems (e.g., group selection whenever feasible), consider leaving naturally regenerated deciduous trees; however, more evidence is needed to determine the effect of these management strategies on weevil populations or attack rates.

Silviculture Considerations

Crop Tree Establishment

- Plant at higher densities (= 1600 trees per hectare).
- Plant a mix of genetically resistant and non-host trees; avoid spruce monocultures.

Plantation Maintenance

- Increasing the planting density (= 2.5-m spacing) of species mixes, or planting under shade trees or nurse crops, induces height growth competition with minimal terminal diameter growth. This forces laterals of attacked trees to "straighten" quickly, which reduces stem deformities. This strategy also increases shade, which cools sites and may reduce weevil survival. Species mixes reduce stand susceptibility.
- Delay spacing until trees are about 7 m tall.
- Consider pruning and destroying infested leaders only under very limited circumstances. Contact the B.C. Ministry of Forests regional entomologist.

CHEMICAL

- Dimethoate (a liquid systemic insecticide) is the only chemical registered in Canada against spruce weevil. Weevils are especially susceptible during fall when they feed on new growth in the upper crown. Multiple applications are often necessary. Chemical applications are seldom used operationally.

Spruce/White Pine Weevil – Southern Interior Forest Region

Potential Effects on Productivity

- Damage includes tree leader mortality, height growth reduction, and increased susceptibility to decay organisms. Heavy attack can result in 3–4 years of height growth loss; small trees sometimes die.
- Although timber volumes in some weevil-attacked stands may not be substantially affected, concern surrounds the recovery of lumber from damaged, deformed trees. Leader mortality results in the laterals competing for apical dominance, which causes forking or heavy branching. In British Columbia, spruce terminal weevils inflict up to $500 million dollars of timber damage per year.
- The SWAT (*S*pruce *W*eevil *AT*tack) Decision Support System enables evaluation of weevil incidence and management effects on growth and yield in British Columbia; however, these evaluations are currently conducted by the B.C. Forest Service and are not available to outside users (*www.pfc.forestry.ca/entomology/weevil/manage_e.html*).

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Western Gall Rust – Southern Interior Forest Region

B.C. Ministry of Forests

Damage from western gall rust.

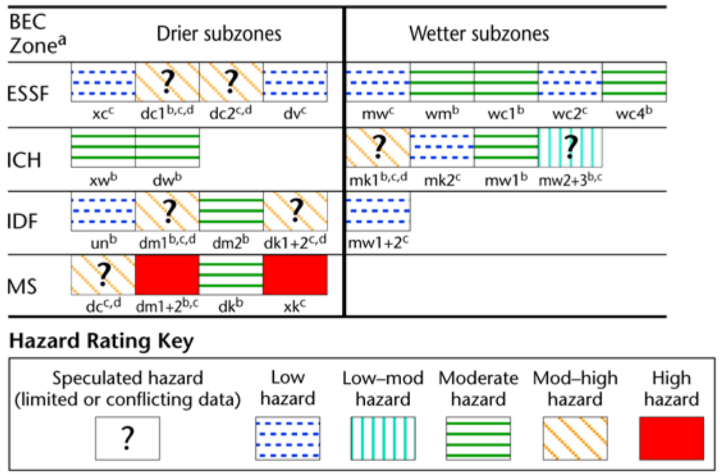
Characteristics of Susceptible Stands

- Young, vigorous, highly managed stands (occurs in natural forests, nurseries, and plantations)

General Information

- Western gall rust is the most common stem rust of hard pines in western Canada.
- Unlike other important stem rusts, western gall rust does not require an alternate host to complete its life cycle, as infection occurs directly from pine to pine.
- Masses of orange-yellow spores, produced annually in spring and early summer (May–July), disperse from galls during warm, windy weather. Germination requires a period of high humidity. Secondary invaders, including hyperparasitic fungi, insects, or mycoparasites, can kill galls. Dead galls remain on the tree.
- Infection incidence varies greatly from year to year, with years of abundant infection designated as "wave" years.
- Wind-dispersed spores land and germinate on the current year's shoots or needles soon after budbreak. Irregular, woody, rounded to pear-shaped swellings appear 1.5–2 years later.

Hazard Rating[1]



[a] See Meidinger and Pojar (1991) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.
[b] Braumandl and Curran (1992).
[c] Lloyd *et al.* (1990).
[d] B.C. Ministry of Forests and B.C. Ministry of Environment (1996).

[1] The hazard table includes information only for those biogeoclimatic subzones found in the former Kamloops or Nelson forest regions. For information on subzones in the former Cariboo Forest Region, see Swift *et al.* 2002.

- All galls initially form on 1-year-old growth. Galls continue to increase in diameter as the host tree grows, typically reaching 5–10 cm, with larger galls sometimes developing on main stems; these galls can grow to 30 cm in diameter before killing the tree.
- Eventually, desiccation causes infected stems or branches beyond the galled area to die.

Hosts: Lodgepole, ponderosa, and jack pines

Silviculture Considerations

- Survey young stands to determine infection levels.

Regeneration and Establishment

NURSERIES

- Do not grow susceptible pine in outdoor nursery beds that are directly surrounded by infected pine; however, sanitation is difficult, if not impossible, because gall rust spores can travel hundreds of kilometres.
- Use disease-free nursery stock and cull seedlings with stem swellings before transplanting.
- When the rust is fruiting in surrounding stands within 500 m, protect nursery stock with fungicidal sprays.

PLANTING

- Plant alternative species (limit lodgepole and ponderosa pines, especially in high-hazard ecosystems).
- To compensate for future mortality, increase target stocking of the post-treatment stand.

Plantation Maintenance

- Sanitation spacing or thinning of infected stands that are 10 years of age or less may result in understocked stands; after 10 years, the risk of stem infection is reduced. Remove trees in the spring before sporulation begins.

Potential Effects on Productivity

- The highest level of damage occurs on trees under 10 years of age, since most of these infections occur on the main stem.
- Young trees are killed outright (as the rust mycelium girdles and kills the stem), or heavy infection stunts stems, which predisposes them to wind or snow breakage.
- Distorted form and shape also reduces the commercial (crop trees) and aesthetic (ornamentals and Christmas trees) value of these trees.
- Damage on mature trees is not significant, as most infections occur on branches.
- Branch galls do not result in serious growth losses or affect the overall health of the tree, but do help to spread the disease.

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Western Hemlock Looper – Southern Interior Forest Region

B.C. Ministry of Forests

Western hemlock looper larvae.

Characteristics of Susceptible Stands

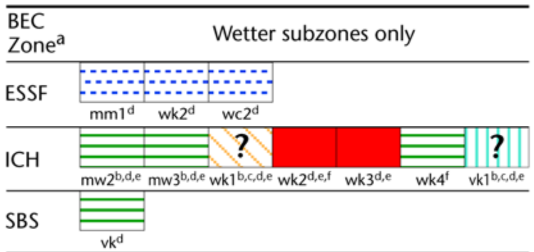
- Valley bottoms with mature western hemlock (over 120 years old)
- South of 56°N latitude
- Sea level to 1400 m elevation
- More than average amounts of precipitation and cooler temperatures
- Dense stands
- Multi-layered stands

General Information

Major Life Cycle Events

- The western hemlock looper overwinters as eggs laid on moss, lichens, or bark.
- Eggs hatch from late May to early June and larvae are present from late July to early September.
- Young larvae feed on new foliage in the upper crown, but mature larvae feed on all ages of foliage.
- Larvae are wasteful feeders and only partially consume needles.
- Mature larvae are quite mobile and produce an abundance of silk webbing, which is very evident in defoliated stands.
- Outbreak populations can remove nearly all the new and old needles in a single season.
- Pupation occurs from late July to early September on foliage, moss, lichen, bark crevices on tree trunks, or in the duff.
- Adults emerge in 10–14 days and fly throughout September and October.
- Outbreaks generally last 3–4 years.

Hazard Rating



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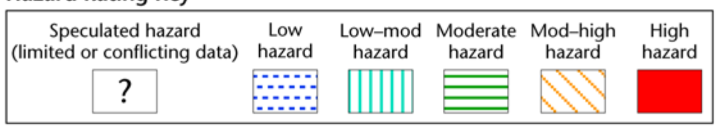

[a] See Meidinger and Pojar (1991) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.
[b] Lloyd *et al.* (1990).
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[f] Personal communication: Leo Rankin, Forest Entomologist, Southern Interior Forest Region, B.C. Ministry of Forests, Kamloops, B.C.

Hosts: Western hemlock; Douglas fir, Western redcedar, hybrid spruce, and western white pine are also defoliated

- During outbreaks other hosts include true firs (amabilis, grand, subalpine), spruces (Engelmann, hybrid, Sitka), western larch, and almost any other foliage, including broadleaved forest trees and shrubs. All tree ages are susceptible.

Harvest Considerations

- Harvesting that promotes the development of a single canopy stand is preferable.

Silviculture Considerations

Regeneration and Establishment

- Maintain various stand age classes and species mixtures across the landscape (< 50% western hemlock or western redcedar).

Plantation Maintenance

- Well-spaced stands are less susceptible.
- For direct control, conduct spray programs. The biological control agent, *Bacillus thuringiensis* var. *kurstaki* (Btk), is a registered product.
- Spray Btk when the western hemlock looper population is increasing. Monitoring systems provide outbreak prediction and expected defoliation thresholds. Contact the B.C. Ministry of Forests for more information.
- Current research at the University of Victoria and the Canadian Forest Service's Pacific Forestry Centre aims to enhance the utility of a naturally occurring, looper-specific nuclear polyhedrosis virus.

Potential Effects on Productivity

- Western hemlock is intolerant of defoliation. Mortality can occur after only 1 year of severe (> 60%) defoliation; trees may continue to die up to 4 years after western hemlock looper populations have collapsed.
- Top die-back and subsequent decay are significant in severely defoliated stands.
- Bark beetle populations can develop in defoliated Douglas-fir or spruce stands.

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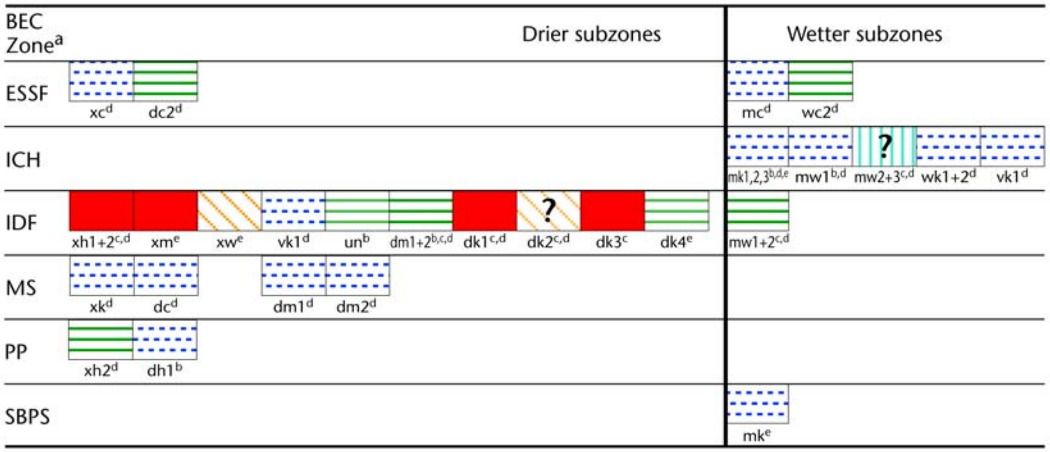
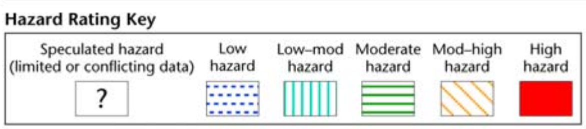
Western Spruce Budworm – Southern Interior Forest Region

Hazard Rating





[a] See Meidinger and Pojar (1991) for an explanation of Biogeoclimatic Ecosystem Classification (BEC) zone, subzone, and variant abbreviations.
[b] Braumandl and Curran (1992).
[c] B.C. Ministry of Forests (1995).
[d] Lloyd *et al.* (1990).
[e] Personal communication: Leo Rankin, Forest Entomologist, Southern Interior Forest Region, B.C. Ministry of Forests, Kamloops, B.C.

Characteristics of Susceptible Stands

- Older, relatively pure stands of Douglas-fir (> 80%)
- Stands with a mixture of true firs and Douglas-fir
- Dense and stressed stands
- Multi-layered stands
- 350–1460 m elevation
- Warm, dry sites
- Suppressed and intermediate trees

General Information

- Western spruce budworm is British Columbia's most destructive defoliator.
- Outbreaks are influenced primarily by climate and weather, and therefore fluctuate in an irregular and unpredictable manner.
- Western spruce budworm has a 1-year life cycle.

Major Life Cycle Events

- Moths emerge and mate from late July to early August. Within 7–10 days, females deposit about 150 eggs on the underside of needles, and then die.
- Egg-laying adults prefer the tallest trees; larvae are blown to shorter, intermediate, or overtopped trees. Larvae hatch in about 10 days; they do not feed, but seek sheltered places under bark scales and lichens, and then spin silken tents called "hibernacula." Larvae overwinter in the hibernacula.
- Larvae re-emerge in late April or May and begin mining into year-old needles, closed buds, or newly developing vegetative or reproductive buds; after about 2 weeks, they enter developing buds.
- As new shoots flush, larvae spin loose webs among the needles and feed on the new foliage. Adjacent shoots are often webbed together, appearing twisted or stunted. This webbing functions as a feeding shelter, and provides some protection from predators and parasites.
- New foliage, which is normally the preferred food, is usually consumed entirely or destroyed before larvae start to feed on older needles.
- On some hosts, larvae favour developing male flowers and conelets as food. Larvae will mine and sever terminal and lateral shoots on western larch.
- Larvae become full grown in early July, about 30–40 days after leaving their overwintering sites.
- As larvae mature, the webbed branch tips on which they have fed turn reddish-brown. Larvae pupate for about 10 days in webs of silk.

Canadian Forest Service

Adult western spruce budworm.

Hosts: Douglas-fir, true firs (grand fir and amabilis fir), western larch; Engelmann and hybrid spruce are minor hosts

Harvest Considerations

- Keep single-storied stands thrifty (clear cut, patch cut, and some selection can be used).
- If possible, promote early harvesting of mature trees and reduce uneven-aged multi-storied stands.
- Western spruce budworm can be a major concern in multi-storied stands. Keep stands relatively open to reduce damage to the understorey by budworms that descend from the overstorey.

Silviculture Considerations

Regeneration and Establishment

PLANTING

- Promote species mixtures.
- Consider converting stands to non-host species (i.e., lodgepole pine, ponderosa pine, and western redcedar).

Plantation Maintenance

- Fertilizing and thinning may benefit moderately infested stands by increasing individual tree growth; this strategy may not have a large effect on insect abundance.

MICROBIAL INSECTICIDES

- For direct control, consider conducting spray programs. Acephate (Orthene®) and carbaryl (Sevin®) are registered for direct control, although the biological control *Bacillus thuringiensis* var. *kurstaki* (Btk) is most commonly used.
- Monitoring systems are available that provide outbreak prediction and expected defoliation thresholds. Contact the B.C. Ministry of Forests for more information.

Western Spruce Budworm – Southern Interior Forest Region

Potential Effects on Productivity

- Western spruce budworm damage includes the killing of buds and stripping of current-year foliage, primarily in the upper crown.
- In severe infestations, old foliage is also destroyed.
- Budworms are wasteful feeders that consume only parts of needles, chewing them off at their bases. Trees usually recover unless severe defoliation is repeated for 3–5+ years.
- Repeated budworm defoliation causes scattered mortality, lowered growth rates, and reduced volumes and lumber quality.
- Successive defoliation may cause top die-back and bole deformities.
- Trees may take several years to resume normal growth after an outbreak ends. Therefore, root disease, bark beetles, loss of vigour, and other causes may lead to tree mortality, even though the infestation has subsided.

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White Pine Blister Rust – Southern Interior Forest Region

B.C. Ministry of Forests

Damage from white pine blister rust.

Hazard Rating

White pine is at high risk from white pine blister rust anywhere in its range; lower hazard subzones are those with lower populations of white pine (Lloyd *et al.* 1990; Braumandl and Curran 1992).

Characteristics of Susceptible Stands

- All sites where susceptible species are present
- Stands on slopes, or in areas subject to cold air ponding
- Open-grown pine stands
- Wetter sites
- Five-needle (soft) pines are hosts, including western white pine, whitebark pine, limber pine, and 5-needle exotic pines

General Information

- White pine blister rust is a non-native obligate parasite.
- Most natural populations of five-needle pines are highly susceptible.
- Most cankers on young trees occur within 2.5 m of the ground; in older trees, the rust is often confined to isolated branches or the upper crown.
- Branch and stem cankers on young bark are initially diamond-shaped with orange margins.
- Established cankers, and those on older stems, have roughened, dead bark, often with resinosis.
- White pine blister rust requires two types of hosts to survive: white pines and an alternate host. The commonly known alternate hosts are *Ribes* spp. (wild currants and gooseberries). Two new alternate hosts were recently confirmed: sickletop lousewort (*Pedicularis racemosa*), a common perennial herb in montane and subalpine habitats; and scarlet paintbrush (*Castilleja miniata*). Both of these species commonly occur along the western arm of whitebark pine's distribution (from British Columbia to the Sierras). They tend to occur in habitats more mesic than whitebark pine, but ranges do overlap.
- White pine blister rust has a complex life cycle that takes approximately 4 years.

Major Life Cyle Events

- **Year One, fall**: Basidiospores are produced on the alternate host's foliage and wind-blown to nearby pine, infecting the current year's needles on the lower branches of the crown. The fungus grows into the branch bark and phloem and eventually into the stem.
- **Year Three**: Symptoms of infection become visible with the development of branch or stem cankers.
- **Year Three, summer**: Pycniospores are produced by cankers.
- **Year Four, spring**: White aecial blisters are produced on the cankers during the spring, followed by orange aesciospores. Both pyciniospores and aeciospores are wind-blown and infect the alternate host. Yellow-orange pustules (uredinia) appear on the underside of the foliage of the alternate host. Chlorotic or necrotic spots occur on the corresponding upper side of the leaves. Urediniospores, teliospores, and then basidiospores are produced and carried back to pine needles to begin the life cycle again.
- **Year Four, mid-late summer:** Brownish hair-like structures (telia) form on the lower leaf surface in place of the uredinia. Heavily infected *Ribes* leaves can appear chlorotic and necrotic, and are sometimes shed prematurely.

Hosts: White pines (whitebark, western white, and limber pine)

Silviculture Considerations

- If white pine is managed commercially, white pine blister rust must be managed as well.
- Eradicating the alternate host is not practical.

Regeneration and Establishment

- When regenerating white pine, use seed from trees that have been bred for blister-rust tolerance.

Plantation Maintenance

- Fell all lethally infected trees; these include trees with stem cankers, or branch cankers less than 15 cm from the stem.
- In plantations established using white pine seed from non-improved sources, or in stands with natural white pine, prune branches to a height of 3.0 m in two lifts, pruning to one-half the total tree height each time.
- Although time consuming, blister rusts can be excised on high-value individual trees. Remove the live bark and cambial tissue 5 cm beyond the leading edge of a stem canker, or the base of a branch with a lethal canker, and 20 cm past the bottom and top edge of the visible canker margin.

Potential Effects on Productivity

- The portion of the tree or branch beyond a blister rust canker usually dies; in older trees, this is usually confined to isolated branches or the upper crown.
- Tree stems may be flattened. Trees infected for several years are identified by the presence of dead branches (red flagging), especially in the lower crown, and dead tops.
- Most infected young trees are killed within a few years; mortality may reach 90% of a stand.
- White pine blister rust is responsible for the decline of white pine, whitebark pine, and other five-needle pines in North America.

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Test Your Knowledge . . .

Southern Interior Forest Region: Forest Health Stand Establishment Decision Aids

How well can you recall some of the main messages in the preceding extension note? Test your knowledge by answering the following questions. Answers are at the bottom of the following page.

1. If black army cutworm damage is expected when seedlings are planted, the simplest and safest approach is to:
   A) plant dry sites early in the spring
   B) plant moist sites early in the spring
   C) delay planting of moist sites one year

2. Black stain root disease infection centres should be left unthinned and surrounded by an unthinned buffer zone of:
   A) 3–5 m
   B) 6–8 m
   C) 8–10 m
   D) 12–14 m

3. Comandra blister rust will attack pines of any size or age.
   A) True
   B) False

4. Which of the following is *NOT* a "telial" host of comandra blister rust:
   A) yellow toad-flax
   B) false toad-flax
   C) comandra
   D) bastard toad-flax

5. In wet years, the fruiting bodies of Rhizina root disease will more commonly appear in:
   A) February
   B) April
   C) June
   D) August

6. On sites infected with spruce weevil, spacing should be delayed until trees reach a height of:
   A) 5 m
   B) 7 m
   C) 9 m
   D) 11 m

. . . continued on next page

Test Your Knowledge . . .

Southern Interior Forest Region: Forest Health Stand Establishment Decision Aids

. . . continued from previous page

7. Nursery stock should be protected with fungicidal sprays when western gall rust is fruiting in surrounding stands that are within:
   A) 100 m
   B) 300 m
   C) 500 m
   D) 700 m

8. Western hemlock looper outbreaks generally last:
   A) 1–2 years
   B) 1–4 years
   C) 2–3 years
   D) 3–4 years

9. After leaving their overwintering sites, western spruce budworm larvae become full grown in about:
   A) 30–40 days
   B) 40–50 days
   C) 50–60 days
   D) 60–70 days

10. Fill in the blank. All lethally infected white pine blister rust trees should be felled, including trees with stem or branch cankers less than ______ from the stem:
   A) 10 cm
   B) 15 cm
   C) 20 cm
   D) 25 cm

Answers

1. B – Moist sites should be planted early in the spring. Planting of sites where moisture stress is expected should be delayed for 1 year.

2. C – An 8–10 m unthinned buffer zone should be left around infection centres.

3. A – True, although pine stands 5–30 years old are the most susceptible.

4. A – Yellow toad-flax is an escaped ornamental brought to this country from Europe.

5. D – In wet years, fruiting bodies are more common in late summer to fall.

6. B 7. C 8. D 9. A 10. B