Potential Approaches to Integrating Silvicultural Control of Mountain Pine Beetle with Wildlife and Sustainable Management Objectives

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Abstract

There are 195 vertebrate species occurring in mountain pine beetle (*Dendroctonus ponderosae* Hopkins) infested areas in interior British Columbia that will likely be impacted by beetle control measures. The effects of these measures on wildlife will depend on whether they increase or decrease the availability of critical habitat attributes such as large trees, dead and dying trees, down wood, shrubby undergrowth, continuous canopy cover, and deciduous trees. Shifting the forest age class distribution to early seral stages to reduce landscape susceptibility to mountain pine beetle attack will harm many wildlife species that are dependent on mature forest conditions, but will benefit the few species that thrive in more open habitats. In contrast, the conversion of lodgepole pine forests to non-pine tree species, and fall and burn treatments, should have relatively minor impacts. The effects of many beetle control measures on wildlife will devolve to the effects of tree retention level on wildlife. Manipulating the tree retention level, and the size, location and dispersion pattern of residual trees and tree patches can significantly advance wildlife management goals. We conclude this paper by suggesting potential approaches to integrating mountain pine beetle control with wildlife and sustainable management objectives.

Introduction

Many management options that are being implemented to control the mountain pine beetle may not be favourable to forest wildlife species, many of which depend on mature seral stages for at least some if not all of their habitat requirements (Bunnell and Chan-McLeod 1997). The selective removal of large-diameter trees, and the creation of young age-class distributions that largely exclude trees older than 80 years, reduce susceptibility to mountain pine beetle attack, but negatively impact vertebrate species that depend on older forests or large-diameter trees. Similarly, spacing to improve tree vigour and resistance to mountain pine beetles has raised concerns of compromised thermal cover and snow interception for ungulates in winter (Whitehead 2002). An even graver threat to habitat values are large-scale clearcut harvesting, which is the only effective control for severe mountain pine beetle infestations in the middle

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of epidemic areas. The catastrophic nature of the mountain pine beetle epidemic, and the silvicultural controls that must be implemented to contain its damage, have immense implications for wildlife and non-timber resources.

The successful integration of beetle control with wildlife and sustainable management objectives requires an understanding of fundamental wildlife needs. The objective of this paper is to provide the foundation from which researchers and managers can develop and evaluate potential strategies for integrating beetle control with wildlife and sustainable management objectives. We will achieve this by: 1) providing an overview of wildlife species that will potentially be impacted by mountain pine beetle controls, and their habitat requirements; 2) considering some likely consequences of beetle control measures on wildlife species occurring within beetle infested regions; and 3) suggesting potential approaches to integrating mountain pine beetle with wildlife and sustainable management objectives.

Wildlife Species Occurring in Beetle-Infested Regions

We tallied 195 vertebrate species occurring in beetle-infested regions in interior British Columbia (BC). These comprise of 140 birds, 49 mammals, and 6 herptiles (Appendices 1 and 2). This tally was based on the 2002 mountain pine beetle distributions and therefore may be conservative, as the infestation has spread to a much greater area.

There are at least nine wildlife species occurring in beetle-infested areas that are considered to be at risk (Appendices 1 and 2). These comprise of five mammals (4 blue-listed; 1 red-listed) and four birds (2 blue-listed; 2 red-listed). Twelve additional species that occur within the range of the mountain pine beetle, though not at risk within beetle-infested regions, are at risk elsewhere in the province.

The woodland caribou (*Rangifer tarandus caribou* Linnaeus) is an at-risk species that epitomizes the conflict between timber harvesting and habitat requirements. It is a mature-forest-dependent species requiring extensive areas of continuous old-growth forests (Smith et al. 2000; Apps et al. 2001) to avoid predation. In winter, woodland caribou crater through the snow to feed on terrestrial lichens, so snow interception by a closed canopy is very important in dictating food availability. Where terrestrial lichens are not accessible because the snow is too deep or crusty, caribou forage instead on arboreal lichens (Johnson et al. 2001) that accumulate slowly in old-growth trees.

Wildlife Habitat Requirements

In general, six forest stand structures are particularly important as wildlife habitat:

- large trees;
- dead and dying trees;
- down wood;
- shrubby undergrowth;
- canopy cover;
- deciduous trees

These components must be maintained in the form and quantities needed to support viable populations of native fauna.

Large trees are important for many reasons. First, they have very deep and complex crowns, which provide a diversity of niches for birds and small mammals, including a microclimatic gradient from high exposed radiation environments at the top to buffered environments toward the forest floor (Spies and Franklin 1996). In addition to vertical niche stratification, horizontal stratification is sometimes also evident, with different species occupying areas at the edge and at the core of the crown. Second, large trees have rough bark, which harbors more arthropods for bark gleaners (Adams and Morrison 1993) and provides more opportunities for bats and birds (e.g., brown creepers, *Certhia americana* Bonaparte) to nest under the bark. Large trees are also big enough to be used by large species such as black bears (*Ursus* *americanus* Pallas) (Oli et al. 1997). Furthermore, they are older and tend to have the heart rot conditions that are favourable to many wildlife species.

In fact, it is the dead and dying trees that will support the greatest diversity of species, since sound trees are rejected by even strong cavity-nesters in nest tree selection. Heartwood decay has been shown to be the most important factor in tree selection by primary cavity-nesting birds in interior Douglas-fir (*Pseudotsuga menziesii* Mirb. Franco) forests (Harestad and Keisker 1989), and zones of rotten wood, such as those occurring under fungal entry points in broken tops or branches, are selected to reduce the energy demands of excavating nest sites (Harmon et al. 1986). Trees or snags that have a soft interior core but a hard exterior shell are ideal, as this allows easy excavation without compromising the protective shell. When a snag has decayed to the point where it is completely soft, then its value is primarily as a foraging site for insectivores and as a source of down wood.

Downed wood is used by more than 179 forest vertebrates in the Pacific Northwest (Thomas 1979). Initial use of newly created downed wood is primarily as perches and cover, but use becomes internal as the decay progresses. Loose bark provides places for hiding and thermal cover, while highly decayed logs are burrowed by small mammals, which in turn facilitates access by amphibians and reptiles (Harmon et al. 1986). The use of downed wood as a foraging medium by insectivores probably peaks toward the middle to late stages of decay (Harmon et al. 1986). Downed wood also modifies the microclimate by evening out extreme fluctuations in environmental conditions, and by holding in the moisture that is vitally important for amphibians (Aubry et al. 1988; Grover 1998).

The role of downed wood is complemented by that of understory vegetation, which provides nesting sites, cover (Althoff et al. 1997), and food in the form of berries, foliage, seeds, and associated ectomycorrhizal fungi and insects (Carey and Johnson 1995).

Canopy cover is another structural attribute that is directly affected by forest practices. Many species such as the marten require continuous mature forest cover to move around and satisfy its requirements. Dense canopies provide better thermal cover and intercept more snow; while open stands allow more light to reach the forest floor and encourage forage production. In general, deep crowns are preferred to shallow crowns because this allows for vertical stratification. Canopy complexity is hypothesized to promote niche differentiation for forest organisms, nutrient cycling, improved invertebrate communities, and dispersal opportunities for species that are forest obligates (Swanson and Franklin 1992).

Deciduous trees are favored by many cavity nesting birds as well as mammals (e.g., fisher, *Martes pennanti* Erxleben) that den in trees (Paragi et al. 1996). In part, this is because they are shorter-lived and produce the right kind of decay conditions earlier in the rotation. The rich litter layer encourages the proliferation of invertebrates (Valovirta 1968; Suominen et al. 2003) by providing favorably moist conditions, food resources, and high calcium concentrations for gastropod shell formation (Karlin 1961; Valovirta 1968). The high invertebrate populations in turn encourage populations of small mammals and amphibians. Small mammals are also attracted to the unique fungal and lichen associations, while amphibians also benefit from the moist physical conditions.

Potential Impacts of Mountain Pine Beetle Controls

One prescription for reducing landscape susceptibility to mountain pine beetle attack is to shift the age class distribution to early seral stages. This will benefit species that thrive in open conditions, such as the dark-eyed junco (*Junco hyemalis* Linnaeus), white-crowned sparrow (*Zonotrichia leucophrys* Forster), porcupine (*Erethizon dorsatum* Linnaeus), and snowshoe hare (*Lepus americanus* Erxleben)(Koehler 1990). Increases in open-habitat species may in turn lead to other changes in vertebrate assemblages. For example, as snowshoe hare populations go up, so will predators such as bobcats (*Lynx rufus* Schreber) because their abundance is highly dependent on the prey base. Conversely, the abundance of species dependent on mature forests will decline. These include the fisher (Carroll et al. 1999), pine grosbeak (*Pinicola enucleator* Linnaeus), Hammond's flycatcher (*Empidonax hammondii* Xantus de Vesey), boreal red-backed vole

(*Clethrionomys gapperi* Vigors), and woodland caribou (Smith et al. 2000). For these species, total numbers will decline and sub-populations may be in may be in danger of extirpation.

Conversion of lodgepole pine (*Pinus contorta* Pinaceae) forests to non-pine tree stands should have relatively minor impact on wildlife habitat. Although lodgepole pine provides hiding and thermal cover for many species, its needles are eaten by blue (*Dendragapus obscurus* Say) and spruce (*Dendragapus canadensis* Linnaeus) grouse in the winter (Zwickel and Bendell 1970; Pendergast and Boag 1971), and its seeds are consumed by many songbirds and small mammals (Lotan and Perry 1983), forest vertebrates should be able to derive similar benefits from fir or spruce. In fact, the conversion of pine to non-pine species may benefit some wildlife. For example, spruce seeds are preferred by red squirrels (*Tamiasciurus hudsonicus* Erxleben) even though lodgepole pine seeds are an important part of the diet.

Silvicultural control of mountain pine beetle generally requires some form of tree removal, whether the objective is salvage logging, sanitation harvesting, pine removal, spacing to improve tree vigour, or beetle proofing. The effects of many beetle control measures may therefore devolve largely to the effects of tree retention level on forest wildlife. Our preliminary results for coastal ecosystems suggest that vertebrate species diversity remains relatively constant at residual tree retention levels between 20% and 100%. Species diversity declines precipitously only when less than 20% of the trees are retained within the cut block. These results are consistent with our understanding of wildlife habitat requirements; in moderately open stands, early-seral wildlife species replace the late-seral wildlife species that are lost.

In contrast to species diversity, relative abundance of individual wildlife species does not stay constant over a wide range of retention levels. For mature forest species such as the Hammond's flycatcher, a positive correlation is observed between tree retention level and abundance. Similar to species diversity however, the steepest part of the curve is at retention levels below 20%. This implies that slight changes in retention level at the low end will result in dramatic differences in flycatcher abundance. For early-seral forest species such as the dark-eyed junco, a negative correlation is apparent between tree retention level and abundance. As before, the sensitivity of junco populations to changes in retention level is most marked at retention levels below 20%. This again supports the conjecture that minor manipulation of retention levels at the low end can strongly alter the vertebrate community.

In addition to retention level, the spatial dispersion of residual trees within the cut block will govern the effects of tree removal on wildlife species. Our data on the coast indicates that some songbirds respond more strongly to dispersion pattern than they do to retention level. For a given retention level, residual trees left in aggregated patches will retain wildlife communities most closely resembling those in old-growth control forests. In contrast, residual trees left either as individual scattered stems or in small clusters will not maintain mature-forest dependent species, and in fact, may only support avian communities normally associated with clearcuts. Our preliminary results for songbirds are consistent with earlier research on small mammals indicating the superior benefits of tree patches as compared to individual residual trees (Sullivan and Sullivan 2001).

Beetle control measures that retain residual trees as aggregated patches should consider the effects of tree patch size on wildlife species. Larger tree patches are more likely to attract amphibians moving through the cutblock, and are significantly more likely to be used as habitat, at least in the short term. Chan-McLeod's research in coastal BC indicated that virtually all radio-harnessed frogs released at the base of individual trees or inside small tree clusters left the site within 72 hours, but the proportion that left decreased curvilinearly with increasing patch size. In contrast, no frogs left streamed tree patches that were at least 0.8 ha. This threshold patch size corresponded to Merrill's (1994) recommended minimum patch size of 0.8 ha for birds. Schieck et al. (1995) concurred that there were no incremental benefits to patches bigger than 4 ha.

Beetle control measures that involve some form of burning will have varying effects on wildlife. Burning *per se* is not detrimental to wildlife – wildfires often lead to higher faunal species richness and abundance (Bock and Lynch 1970; Apfelbaum and Haney 1981; Simon et al. 2002) because they leave behind pockets of live as well as standing dead trees. In fact, some wildlife species that are absent from harvested cutblocks are found almost exclusively in old-growth forests or recent burns (Gagnon et al. 1999). For example, the black-backed woodpecker (*Picoides arcticus* Swainson) selectively feed on charred trees and exploit only newly burnt forests (Murphy and Lenhausen 1998). However, prescribed burns do not mimic wildfires because they burn much more homogeneously and may eliminate key habitat attributes such as snags and downed wood. Sizeable prescribed burns may, therefore, have some detrimental effects on wildlife habitat. Conversely, prescribed burns may benefit wildlife by encouraging early green up and shrub growth, and by removing slash piles that may hinder movement by deer. Fall-and-burn areas, which are generally very small, will have relatively minor impacts and may enhance species richness by providing small openings within a largely intact forest. In general, habitat generalists, omnivores, and species that nest on the ground or in shrubs would be least sensitive to burn treatments (Morisette et al. 2002).

Integrating Mountain Pine Beetle Control with Wildlife and Sustainable Management Objectives

In many cases, broadly defined control measures have flexible elements that can be tailored to benefit wildlife and sustainable management indicator values. For example, the spacing and harvesting prescriptions for mountain pine beetle management are highly analogous to the variable-retention harvesting that is increasingly being applied in working forests in the Pacific Northwest. As discussed above, the location and dispersion pattern of residual trees and tree patches, and even slight differences in retention level, can yield significantly different impacts on wildlife populations.

The first potential strategy for integrating mountain pine beetle control with wildlife and sustainable management objectives is therefore to incorporate wildlife considerations in partial-cut control measures. Our preliminary results from the coast suggest the following targets may be appropriate:

- Retention levels > 20% to maintain wildlife species occurrence; retention levels > 90% to maintain abundance of mature-forest-dependent species;
- Aggregated pattern for residual trees is superior to dispersed pattern;
- Tree patch size > 0.8 ha;
- Residual trees placed in deeper soils, by riparian, in patches with high snag composition.

These speculated targets would of course have to be evaluated in beetle-infested ecosystems, the wildlife of which may respond differently from those in the coast to partial harvests.

A second potential strategy is to maintain key habitat structures, including live trees, snags, and downed wood whenever possible. Critical habitat attributes should be created through girdling, topping, or stubbing where safety regulations or other factors preclude the maintenance of existing habitat structures. Retained or created habitat structures must however be consistent with wildlife requirements. For example, snags that are less than 25 cm DBH (Bull 1983) will not be used by cavity nesters and, furthermore, will probably not stand for very long because of windthrow. Woodpeckers can be extremely efficient predators of the beetle, especially in epidemic areas (Tunnock 1960; Amman 1984; Bergvinson and Borden 1992) – harvesting efficiencies of mountain pine beetle by woodpeckers often exceeded 90%, while debarking only 5% of the bole surface could reduce the beetle brood by up to 50% (Tunnock 1960; Bergvinson and Borden 1992). However, woodpeckers are often insignificant factors in controlling epidemic outbreaks because they are too limited by the number of nesting sites (Otvos 1965). Enhancement of nest sites for woodpeckers where these are limiting can be rewarding for both wildlife and beetle control. Where nest sites are not limiting, woodpecker densities have increased with beetle density (Koplin 1969).

A third potential strategy is to leave beetle-killed stands in strategic locations that will maximize the benefit to wildlife. This strategy has excellent potential since forest companies will not be able to salvage log all infested stands within the commercial shelf life of the dead trees. On the other hand, such stands can be highly valuable to wildlife. Bull (1983) documented that lodgepole pines were important feeding and nesting sites for at least 8 years after the trees were beetle-killed. We suspect that these stands will have important habitat value for much longer; the 8-year timeframe simply marked the end of Bull's study. For many stands, even those that are heavily infested, live trees will be interspersed amongst the dead trees. Selection of beetle-killed stands where there is a live tree component will further enhance the value of the stand as wildlife habitat.

A fourth potential strategy is to balance silvicultural mosaics at the landscape level as much as possible to satisfy both beetle control and wildlife objectives. Strategies for both beetle control and wildlife objectives agree that it is important not to apply the same silvicultural treatments across the landscape. Extensive homogenous landscapes may increase susceptibility to mountain pine beetle epidemics over time, while failing to meet the requirements of different wildlife species for different habitat types. Any given silvicultural control for mountain pine beetle can benefit some wildlife species but be detrimental to other wildlife species, because there will be widely varying and often opposing habitat requirements. For every management option exercised, there will be winners and losers among wildlife populations, and these tradeoffs must be balanced across the landscape so that species requirements are met at both the stand and landscape levels.

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Appendix 1. Birds occurring in mountain-pine beetle-infested regions in BC.

Species	Latin Name
Blackbird, Brewer's	*Euphagus cyanocephalus*
Blackbird, Red-winged	*Agelaius phoeniceus*
Blackbird, Rusty	*Euphagus carolinus*
Blackbird, Yellow-headed	*Xanthocephalus xanthocephalus*
Bluebird, Mountain	*Sialia currucoides*
Bobolink[2]	*Dolichonyx oryzivorus*
Bunting, Lazuli	*Passerina amoena*
Bunting, Snow	*Plectrophenax nivalis*
Chickadee, Black-capped	*Poecile atricapilla*
Chickadee, Boreal	*Poecile hudsonica*
Chickadee, Mountain	*Poecile gambeli*
Cowbird, Brown-headed	*Molothrus ater*
Creeper, Brown	*Certhia americana*
Crossbill, Red	*Loxia curvirostra*
Crossbill, White-winged	*Loxia leucoptera*
Crow, American	*Corvus brachyrhynchos*
Eagle, Bald	*Haliaeetus leucocephalus*
Eagle, golden	*Aquila chrysaetos*
Falcon, Peregrine[1]	*Falco peregrinus*
Finch, Cassin's	*Carpodacus cassinii*
Finch, Purple	*Carpodacus purpureus*
Flicker, Northern	*Colaptes auratus*
Flycatcher, Alder	*Empidonax alnorum*
Flycatcher, Dusky	*Empidonax oberholseri*
Flycatcher, Hammond's	*Empidonax hammondii*
Flycatcher, Least	*Empidonax minimus*
Flycatcher, Olive-sided	*Contopus cooperi*
Flycatcher, Pacific-sloped	*Empidonax difficilis*
Flycatcher, Yellow-bellied	*Empidonax flaviventris*
Goldfinch, American	*Carduelis tristis*
Goshawk, Northern[3]	*Accipiter gentilis*
Grosbeak, Black-headed	*Pheucticus melanocephalus*
Grosbeak, Evening	*Coccothraustes vespertinus*
Grosbeak, Pine[2]	*Pinicola enucleator*
Grosbeak, Rose-breasted	*Pheucticus ludovicianus*
Grouse, Blue	*Dendragapus obscurus*
Grouse, Ruffed	*Bonasa umbellus*
Grouse, Spruce	*Falcipennis canadensis*
Harrier, Northern	*Circus cyaneus*
Hawk, Cooper's	*Accipiter cooperii*
Hawk, Red-tailed	*Buteo jamaicensis*
Hawk, Rough-legged	*Buteo lagopus*
Hawk, Sharp-shinned	*Accipiter striatus*
Hummingbird, Anna's	*Calypte anna*
Hummingbird, Calliope	*Stellula calliope*
Hummingbird, Rufous	*Selasphorus rufus*
Jay, Gray	*Perisoreus canadensis*
Jay, Steller's[3]	*Cyanocitta stelleri*
Junco, Dark-eyed	*Junco hyemalis*
Kestrel, American	*Falco sparverius*
Kingbird, Eastern	*Tyrannus tyrannus*
Kingbird, Western	*Tyrannus verticalis*
Kingfisher, Belted	*Ceryle alcyon*

Species	Latin Name
Kinglet, Golden-crowned	*Regulus satrapa*
Kinglet, Ruby-crowned	*Regulus calendula*
Lark, Horned[3]	*Eremophila alpestris*
Longspur, Lapland	*Calcarius lapponicus*
Meadowlark, Western[3]	*Sturnella neglecta*
Merlin	*Falco columbarius*
Mockingbird, Northern	*Mimus polyglottos*
Nighthawk, Common	*Chordeiles minor*
Nuthatch, Red-breasted	*Sitta canadensis*
Nuthatch, White-breasted	*Sitta carolinensis*
Osprey	*Pandion haliaetus*
Ovenbird	*Seiurus aurocapillus*
Owl, Barred	*Strix varia*
Owl, Great Gray	*Strix nebulosa*
Owl, Great-horned	*Bubo virginianus*
Owl, Long-eared	*Asio otus*
Owl, Northern Hawk	*Surnia ulula*
Owl, Northern Pygmy[2]	*Glaucidium gnoma*
Owl, Northern Saw-whet[2]	*Aegolius acadicus*
Phoebe, Say's	*Sayornis saya*
Pigeon, Band-tailed[2]	*Columba fasciata*
Raven, Common	*Corvus corax*
Redpoll, Common	*Carduelis flammea*
Redpoll, Hoary	*Carduelis hornemanni*
Redstart, American	*Setophaga ruticilla*
Robin, American	*Turdus migratorius*
Sapsucker, Red-breasted	*Sphyrapicus ruber*
Sapsucker, Yellow-bellied	*Sphyrapicus varius*
Shrike, Northern	*Lanius excubitor*
Siskin, Pine	*Carduelis pinus*
Solitaire, Townsend's	*Myadestes townsendi*
Sparrow, American Tree	*Spizella arborea*
Sparrow, Brewer's	*Spizella breweri*
Sparrow, Chipping	*Spizella passerina*
Sparrow, Clay-colored	*Spizella pallida*
Sparrow, Fox	*Passerella iliaca*
Sparrow, Golden-crowned	*Zonotrichia atricapilla*
Sparrow, Harris's	*Zonotrichia querula*
Sparrow, Lark	*Chondestes grammacus*
Sparrow, Lincoln's	*Melospiza lincolnii*
Sparrow, Savannah	*Passerculus sandwichensis*
Sparrow, Song	*Melospiza melodia*
Sparrow, Swamp	*Melospiza georgiana*
Sparrow, Vesper	*Pooecetes gramineus*
Sparrow, White-crowned	*Zonotrichia leucophrys*
Sparrow, White-throated	*Zonotrichia albicollis*
Starling, European	*Sturnus vulgaris*
Swallow, Bank	*Riparia riparia*
Swallow, Barn	*Hirundo rustica*
Swallow, Northern Rough-winged	*Stelgidopteryx serripennis*
Swallow, Tree	*Tachycineta bicolor*
Swallow, Violet-green	*Tachycineta thalassina*

Appendix 1 (continued). Birds occurring in mountain-pine beetle-infested regions in BC.

Species	Latin Name
Swift, Vaux's	*Chaetura vauxi*
Tanager, Western	*Piranga ludoviciana*
Thrush, Hermit's	*Catharus guttatus*
Thrush, Swainson's	*Catharus ustulatus*
Thrush, Varied	*Ixoreus naevius*
Veery	*Catharus fuscescens*
Vireo, Cassin's	*Vireo cassinii*
Vireo, Red-eyed	*Vireo olivaceus*
Vireo, Warbling	*Vireo gilvus*
Warbler, Black-and-white	*Mniotilta varia*
Warbler, Blackpoll	*Dendroica striata*
Warbler, Cape May[1]	*Dendroica tigrina*
Warbler, Chestnut-sided	*Dendroica pensylvanica*
Warbler, MacGillivray's	*Oporornis tolmiei*
Warbler, Magnolia	*Dendroica magnolia*
Warbler, Nashville	*Vermivora ruficapilla*
Warbler, Orange-crowned	*Vermivora celata*
Warbler, Palm	*Dendroica palmarum*
Warbler, Tennessee	*Vermivora peregrina*
Warbler, Townsend's	*Dendroica townsendi*
Warbler, Wilson's	*Wilsonia pusilla*
Warbler, Yellow	*Dendroica petechia*
Warbler, Yellow-rumped	*Dendroica coronata*
Waterthrush, Northern	*Seiurus noveboracensis*
Waxwing, Bohemian	*Bombycilla garrulus*
Waxwing, Cedar	*Bombycilla cedrorum*
Woodpecker, Black-backed	*Picoides arcticus*
Woodpecker, Downy	*Picoides pubescens*
Woodpecker, Hairy	*Picoides villosus*
Woodpecker, Pileated	*Dryocopus pileatus*
Woodpecker, Three-toed	*Picoides tridactylus*
Wood-pewee, Western	*Contopus sordidulus*
Wren, House	*Troglodytes aedon*
Wren, Marsh	*Cistothorus palustris*
Wren, Winter	*Troglodytes troglodytes*
Yellowthroat, Common	*Geothlypis trichas*

[1]Red-listed

[2]Blue-listed

[3]At-risk elsewhere in BC (outside beetle-infested regions)

Appendix 2. Mammals and herptiles occurring in mountain-pine beetle-infested regions in BC.

Common Name	Latin Name
Mammals	
Common Shrew	*Sorex cinereus*
Dusky Shrew	*Sorex monticolus*
Pygmy Shrew	*Sorex hoyi*
Little Brown Myotis	*Myotis lucifugus*
Western Long-eared Myotis	*Myotis evotis*
Yuma Myotis	*Myotis yumanensis*
Long-legged Myotis	*Myotis volans*
Silver-haired Bat	*Lasionycteris noctivagans*
Big Brown Bat	*Eptesicus fuscus*
Hoary Bat	*Lasiurus cinereus*
Townsend's Big-eared Bat[2]	*Corynorhinus townsendii*
Grizzly Bear[2]	*Ursus arctos*
Black Bear[3]	*Ursus americanus*
Fisher[1]	*Martes pennanti*
Marten	*Martes americana*
Least Weasel	*Mustela nivalis*
Short-tailed Weasel	*Mustela erminea*
Long-tailed Weasel[3]	*Mustela frenata*
Mink	*Mustela vison*
River Otter	*Lontra canadensis*
Wolverine[2]	*Gulo gulo luscus*
Striped Skunk	*Mephitis mephitis*
Coyote	*Canis latrans*
Gray Wolf	*Canis lupus*
Red Fox	*Vulpes vulpes*
Mountain Lion	*Puma concolor*
Bobcat	*Lynx rufus*
Lynx	*Lynx canadensis*
Yellow-Pine Chipmunk	*Tamias amoenus*
Red Squirrel	*Tamiasciurus hudsonicus*
Northern Flying Squirrel	*Glaucomys sabrinus*
Beaver	*Castor canadensis*
Deer Mouse	*Peromyscus maniculatus*
Bushy-tailed Woodrat	*Neotoma cinerea*
Northern Bog Lemming[3]	*Synaptomys borealis*
Brown Lemming	*Lemmus trimucronatus*
Southern Red-backed Vole[3]	*Clethrionomys gapperi*
Heather Vole	*Phenacomys intermedius*
Meadow Vole	*Microtus pennsylvanicus*
Long-tailed Vole	*Microtus longicaudus*
Western Jumping Mouse	*Zapus princeps*
Meadow Jumping Mouse[3]	*Zapus hudsonius*
Porcupine	*Erethizon dorsatum*
Snowshoe Hare[3]	*Lepus americanus*
Elk[3]	*Cervus canadensis*
White-tailed Deer	*Odocoileus virginianus*
Mule Deer	*Odocoileus hemionus*
Moose	*Alces alces*
Woodland Caribou (Mountain)[2]	*Rangifer tarandus caribou*

Common Name	Latin Name
Herptiles	
Long-toed Salamander	*Ambystoma macrodactylum*
Western Toad	*Bufo boreas*
Pacific Treefrog	*Pseudacris regilla*
Spotted Frog	*Rana pretiosa*
Wood Frog	*Rana sylvatica*
Common Garter Snake	*Thamnophis sirtalis*

[1]Red-listed
[2]Blue-listed
[3]At-risk elsewhere in BC (outside beetle-infested regions)