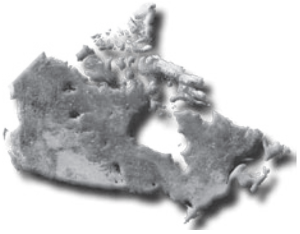

Evaluating effects of large-scale salvage logging for mountain pine beetle on terrestrial and aquatic vertebrates

Fred L. Bunnell, Kelly A. Squires, Isabelle Houde

Mountain Pine Beetle Initiative
Working Paper 2004- 2

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Mountain Pine Beetle Initiative
Working Paper 1

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Abstract

Control of mountain pine beetle can be integrated with wildlife and sustainable forest management objectives through a variety of approaches. At the most fundamental level, the effects of current control measures (i.e. salvage logging) on wildlife populations and sustainable management indicators need to be quantified.

For the scale of salvage logging operations anticipated in British Columbia, there is no literature documenting the effects on vertebrates. This evaluation of the potential effects of large-scale salvage operations is based on natural history features of the resident vertebrate fauna. Likely effects resulting from these features are summarized. The review of ecological relations is in three parts: forest-dwelling terrestrial vertebrates, freshwater fish, and non-forest-dwelling vertebrates. In some instances, salvage practices can be modified to retain potential positive effects on vertebrates; in other instances they can be modified to reduce negative effects.

The report includes recommendations for effectiveness and implementation monitoring, and key research questions. These recommendations are framed within the context of the three broad indicators adapted by the British Columbia Ministry of Water, Air and Land Protection and employed by several companies to assess efforts in sustaining biological diversity.

Résumé

Le contrôle des dendroctones du pin peut être intégré aux objectifs de gestion de la faune et de gestion durable des forêts en adoptant diverses approches. À un niveau fondamental, nous devons quantifier les effets des mesures de contrôle actuelles (c.-à-d., les coupes de récupération) sur les populations d'animaux sauvages et les indicateurs de la gestion durable.

Il n'existe pas de rapports détaillant les éventuels effets des coupes de récupération sur les vertébrés à l'échelle de coupes telles que celles envisagées en Colombie-Britannique. La présente évaluation des effets potentiels des coupes de récupération à grande échelle est basée sur les caractéristiques biologiques des vertébrés résidents. On y donne un résumé des effets possibles compte tenu de ces caractéristiques. Les effets écologiques sont divisés en trois parties : effets sur les vertébrés sylvicoles terrestres, effets sur les poissons d'eau douce et effets sur les vertébrés non sylvicoles. Dans certains cas, les modes de récupérations peuvent être modifiés pour que les effets positifs sur les vertébrés soient préservés. Dans d'autres cas, les modes de récupération peuvent être modifiés pour réduire les effets négatifs.

Le rapport inclut des recommandations concernant la surveillance de la mise en œuvre et de l'efficacité ainsi qu'un certain nombre de questions de recherche clés. Ces recommandations s'inscrivent dans le contexte de trois indicateurs larges adaptés par le ministère de la Protection de l'eau, de l'air et des terres de la Colombie-Britannique et utilisés par plusieurs compagnies pour évaluer les efforts accomplis dans le cadre de la préservation de la diversité biologique.

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Executive Summary

For operations of the scale anticipated in British Columbia, there is no literature documenting effects of salvage on vertebrates. This evaluation of the likely effects of large-scale salvage operations is based on natural history features of the resident vertebrate fauna. Likely effects resulting from these features are summarized. The review of ecological relations is in three parts: forest-dwelling terrestrial vertebrates, freshwater fish, and non-forest-dwelling vertebrates. In some instances, salvage practices can be modified to retain potential positive effects on vertebrates; in other instances they can be modified to reduce negative effects.

The beetle kill itself will potentially benefit about 65% of the resident, terrestrial vertebrate fauna in the short term. Conversely, the kill and associated salvage operations are anticipated to have negative effects on at least 35% of the species present. To attain potential beneficial effects and reduce negative effects, specific actions can be taken at the stand and landscape level.

At the stand level, salvage operations should:

- *Retain species other than lodgepole pine during logging.*
- *Provide small buffers of dead lodgepole pine around retained inclusions of other tree species.*
- *Retain small groups (>0.2 ha) of dead pine.*
- *Control minor vegetation sparingly.*
- *Leave any slash >15 cm in diameter where it lies.*
- *Follow former Forest Practice Code guidelines when harvesting near streams and rivers.*
- *Avoid any mechanical or other disturbances in or within 20m of S3 and S4 streams.*
- *Reserve riparian and upland hardwoods from harvest.*
- *Create tall stumps or stubs as cavity sites where other tree species have not been reserved from harvest and harvest method permits.*
- *Stubs should be restricted to trees >30 cm in DBH or where cavities already exist.*

At the landscape scale, salvage operations should:

- *Plan both areas to be reserved from harvest and areas to be harvested as large blocks.*
- *Avoid salvage in selected areas where intermixed pine represents <40% of the species mix.*
- *Get in and out of salvage areas quickly, and deactivate new roads wherever possible.*
- *Reserve half of each known lodgepole pine ungulate winter range from salvage.*
- *Leave areas should include areas in which there are high densities of fish species that are highly sensitive to salvage logging, and for which the province has high stewardship responsibility.*

Large-scale salvage operations are unlikely to result in positive impacts on freshwater fish. Many of the recommendations made for forest-dwelling terrestrial vertebrates also minimize impacts on freshwater fish and recommendations made for both will also benefit non-forest dwelling vertebrates. This latter group also will benefit from two further recommendations:

- *Retain unharvested riparian buffers around wetlands and lakes.*

- *Avoid log storage within lakes.*

These actions also will help to sustain other groups of organisms, including lichens, bryophytes and non-pest invertebrates. Just as importantly, these recommendations have the effect of continuing economic and social values in the salvage area, by ensuring that some trees are retained for near-term future harvest.

The report concludes with recommendations for effectiveness and implementation monitoring, and key research questions. These recommendations are framed within the context of the three broad indicators adapted by the British Columbia Ministry of Water, Air and Land Protection and employed by several companies to assess efforts in sustaining biological diversity. Specifically,

Indicator 1: During large-scale salvage operations, amounts and area of tree species other than lodgepole pine harvested during large-scale salvage operations do not decline below those expected during normal operations.

Indicator 2: The amount, distribution and heterogeneity of stand and forest structures required to sustain native species richness are maintained over time.

Indicator 3: The abundance, distribution and reproductive success of native species are not substantially reduced by salvage operations.

Introduction and scope

British Columbia currently is experiencing the largest infestation by forest insects ever reported for Canada. The mountain pine beetle (*Dendroctonus ponderosae*), a small insect native to North America, lays its eggs in the bark of mature lodgepole and ponderosa pines (*Pinus contorta* and *P. ponderosa*), and less commonly in other western pine species (Amman 1982; Logan and Powell 2001). Larvae feed on sap and then emerge to infect nearby trees. Trees die within one year of infestation due to the combined effects of beetles and a fungus that is carried by adult beetles.

Periodic pine beetle outbreaks occur naturally, and normally pine beetle infestations are the second major natural disturbance in the central interior, second to fire. The current infestation is the largest ever recorded for the province for as long as data have been acquired – 1910 (Drever and Hughes 2001; Wood and Unger 1996). However, the central interior landscape has been shaped by large disturbances, both fire and insect, so it is possible that the current epidemic is not larger than all previous ones (Steventon 1997).

To date, over 4.2 million ha have been impacted in the province, with the largest concentration in the central interior (BCMoF 2003). The present infestation in British Columbia, though uncommonly large, is still limited largely to lodgepole pine. Lodgepole pine is the most important commercial species in British Columbia, comprising up to 65% of all trees harvested in the Lakes, Quesnel and Prince George Timber Supply Areas (TSAs) (BCMoF 2004). There appears to be nothing that humans can do to limit an infestation once it has reached this size (Drever and Hughes 2001). However, salvage logging can recover part of the potential revenue that is lost as trees die and may slow the spread of beetles to other areas.

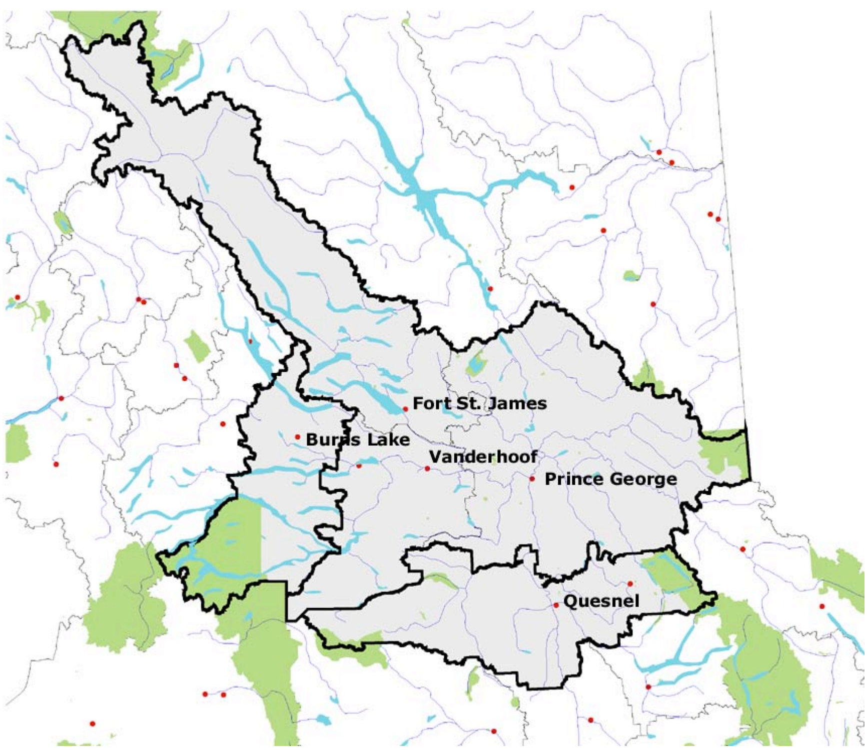

Figure 1. The study area consists of the Lakes TSA, Prince George TSA and Quesnel TSA in central British Columbia.

Initial large-scale salvage logging is targeted to three TSAs: Lakes, Quesnel, and Prince George (Figure 1).

There have been few reported evaluations of effects of salvage logging on resident vertebrates, whether for fire- or insect-killed trees. There has been no evaluation of effects of salvage logging at the scale proposed for British Columbia. The last large-scale salvage operation in the province was for a spruce beetle (*Dendroctonus rufipennis)* outbreak in the area of Bowron Lakes. The current bark beetle outbreak is much more extensive. Because there is no literature dealing with events at this scale, and because it is too early to know the pattern of harvesting, our predictive efforts can be no more than reasoned estimates based on the natural history of vertebrates in the area. Consequences likely will be quite different if riparian areas are harvested along with upland areas, or if all tree species are harvested instead of harvest being limited to lodgepole pine. Under the proposed salvage operations about 4.9 million m^3 of timber will be removed more quickly than was originally planned. This represents increases in the AAC within the study area ranging from 20% to over 60%, most of the increase to allow for salvage logging. In the Lakes TSA, about 28-36% of the harvestable land base will be harvested over the next 20 years (Drever and Hughes 2001).

Large-scale salvage operations will create two broad classes of land: salvaged areas and areas not salvaged. Relative to normal operations, the salvaged areas will experience large changes in the manner in which timber is removed: rate of cut, size of block, location of harvest block, extent and intensity of harvest, and intensity of regeneration. These actions in turn will have profound effects on the amounts and distribution of habitat structures left. Unsalvaged areas with beetle kill also will be dramatically changed. The temporal pattern will be complex, but unsalvaged beetle-killed areas will increase amounts, at least in the short term, of some habitat elements often in short supply: snags, downed wood, shrubs, and likely early seral stages. Many of these consequences are difficult to foresee, especially the temporal patterns over large areas. Our charge is to consider these consequences on vertebrates. Our recommendations focus on sustained and widespread distribution of habitat elements and structures through the future. Part of that can be achieved through various forms of retention. An equally important part is to return salvage logged areas rapidly to operable status, not simply for economic reasons, but to provide sustained habitat elements.

Our scope is all vertebrates, terrestrial and aquatic, known or believed to be present in three TSAs: Lakes, Quesnel, and Prince George (Figure 1). We present our findings for three broad groups: forest-dwelling terrestrial vertebrates, freshwater fish, and vertebrates that are less closely associated with forest cover within the area. The final section outlines a potential approach to effectiveness and implementation monitoring that can be used to determine whether management strategies are effective in minimizing impacts to biodiversity.

Forest-dwelling terrestrial vertebrates

We estimate that 182 forest-dwelling terrestrial vertebrate species breed within the area of the three TSAs (Appendix I). Of these, 127 are birds and 50 are mammals; four amphibians and one reptile also are present. Among these species, six are listed by COSEWIC (Committee on the Status of Endangered Wildlife in Canada) as "threatened" or of "special concern." An additional two species are listed by the BC Conservation Data Center (CDC) – one red-listed and one blue-listed (Appendix I). Four species occur on the provincial list of "Identified Wildlife – 2004" – great blue heron, grizzly bear, wolverine, and caribou. An additional four species are included in the category of ungulate species for which winter range may be required – mule deer, white-tailed deer, elk, and moose. Listed species are treated later in this report.

Only three vertebrates present in the study area are known to seek lodgepole pine as a preferred forest cover and none are restricted to it. The northern ecotype of caribou sometimes seeks lodgepole pine as preferred habitat for winter range. In the southern interior of province, three-toed woodpeckers are found mostly in stands dominated by lodgepole pine and spruce and feed and nest in beetle-infected pine (Steeger and Dulisse 1997; Steeger et al. 1998). The reliance of black-backed woodpeckers on beetle-killed stands also is high. All three species likely will be negatively impacted by large-scale salvage, but the two woodpecker species are more mobile, generally moving between fire- or beetle-killed areas (Hutto 1995), while the caribou appear unable to roam as widely. We view caribou as the species most threatened by salvage logging.

The lack of preference for lodgepole pine among most species derives partially from the fact that lodgepole pine forests are specifically adapted to stand-initiating fires and do not represent a community with long-term stability (Davis et al. 1980; Fischer and Clayton. 1983; Smith and Fischer 1997). The consequences of salvage logging on most vertebrate populations thus stem primarily from the removal of forest cover, or elements of structure upon which some species depend. Because lodgepole pine forests are fire-adapted and owe their existence to relatively frequent disturbance, some vertebrate species can be expected to respond neutrally or positively to large-scale removal of lodgepole pine forests. Others, including the three terrestrial species noted and many freshwater fish species, can be expected to respond negatively.

In sections following, we note key forest attributes to which terrestrial vertebrates respond and likely consequences of large-scale salvage logging on regional populations. Vertebrates also will respond to changes in the beetle-killed areas that are not salvaged, though that is poorly evaluated at the landscape level. The lack of known trajectories of habitat elements in beetle-killed areas limits the ability to forecast likely effects. That is unfortunate, because given that only a portion of the area can be salvage logged, planning over larger scales may be the most effective tool for mitigating effects on resident biodiversity. We have focused on stand-level attributes. These attributes are ordered into two broad groups: those which salvage logging might improve when implemented appropriately, and those for which implementation will have predominantly negative effects. Biodiversity might be enhanced by making early seral stages more hospitable by increasing shrub cover and increasing amounts of larger downed wood. Predominantly negative effects can result from practices with regard to riparian habitat, deciduous stands, cavity sites, and older seral stages. We end this section by summarizing consequences for listed species and noting, when possible, how these can be mitigated.

Encouraging potential positive responses

Early seral stages and habitat generalists

Of the 182 vertebrate species present, 32 prefer relatively large areas of early seral stages (designated “E” in Appendix I). An additional 84 species are relatively insensitive to age of forest cover at the broad scale, or prefer mixtures of stand ages. These are designated “G” or generalist in Appendix I. Such generalist species often require habitat elements more common in older stands, but do not require large amounts of these elements. For example, cavity-nesting waterfowl require only a few larger trees, with heart rot, in riparian areas. Less than half of these 116 species would flourish if large tracts of forest were completely denuded of forest cover. There are four reasons. First, 73 of these species (63%) are riparian associates. Riparian areas must be retained relatively intact (see “Riparian” below). Second, a significant portion of both early seral associates and generalists respond positively to forest edge – they use young seral stages primarily when older forest cover is nearby. Over 40% of these species show strong affinities to edge – 11 early seral associates and 36 seral stage generalists. Third, among these species, some that show no strong affinity for edges will not venture into the middle of larger clearcuts (e.g., bushy-tailed woodrat, red fox, mule deer). Fourth, an additional number of species noted as early seral associates or generalists require only a few additional trees within expansive clearcuts to do well (e.g., American kestrel, violet green swallow). That is, even relatively small groups of remnant trees provide gains in the number of vertebrate species retained during salvage logging.

These values reveal that while a sizeable portion (116/182 = 64%) of the forest-dwelling vertebrate species present prefer either sizable tracts of early seral forest or are generalists with respect to seral stage, many will not occur in significant numbers unless some of the forest is reserved from harvest. The portion sustained is significantly reduced when large clearcuts (greater than about 500 ha) are created. However, only small amounts of standing trees (both alive and dead) help make larger patches of early seral stages favourable for some species.

Leaving all non-pine tree species, rather than simply clearcutting all trees, attains major gains in sustaining vertebrate species. That is true of organisms other than vertebrates, such as some mosses, lichens and not-pest invertebrates, as well (Brodo 1974; Berg et al. 1994). For vertebrates the value likely exceeds 60% of the species present, provided the riparian areas are maintained. A sizeable number of these species will benefit from salvage logging provided other tree species, plus those in riparian areas, are maintained.

- *Retaining species other than lodgepole pine during logging will help retain about 60% of the terrestrial vertebrate species present as well as bryophytes, lichens and non-pest invertebrates.*

In many instances, such retention will be relatively easy to attain because many harvested areas will not be pure lodgepole pine. There will be windthrow from retained patches. Beese (2001) reported windthrow rates as high as 29% in dispersed retention at the MASS site south of Campbell River. Losses from more recently developed retention systems ranged from 4.4% at the Silviculture Treatments for Ecosystem Management in the Sayward (STEMS) study site near Campbell River to 15.9% for retention treatments in Clayoquot Sound (Scott 2004). The largest sample of retention plots is that of Rollerson et al. (2003), who found average losses of 12% along edges of retained patches, but strong regional differences ranging from 7% near Port McNeill and Stillwater to 27% in the Queen Charlotte Islands. Huggard et al. (1999) reported increases over the background rate of 0.2 to 1.6% per year in the harvest treatments at Sicamous Creek. Patterns of damage changed after heavy snowfall, but Huggard et al. (2001) observed that, "…there is no evidence supporting the belief that alternatives to large clearcuts will lead to increased wind damage." Moreover, benefits accrued from reserved patches in terms of non-timber values outweigh the losses incurred.

It is important to note that, in the provisions for uplift in AAC to accommodate salvage operations, it is assumed that stand-level retention will average 20% rather than the 7% assumed for normal forest operations. That level of retention should accommodate retention of patches of other tree species and riparian areas.

The windthrow rates reported above are from live trees and it is unclear whether they will be higher or lower in dead trees without living roots, but with a smaller "sail" area. Beetle-killed trees do remain standing for some time. Agee (1981) reported that 15% of fire- or beetle-killed lodgepole pine were still standing 10 years after being killed. Bull (1983) documented that lodgepole pines were important feeding and nesting sites for at least 8 years after the trees were beetle killed, after which her study ended. Working with another fire-adapted species with serotinous cones (*Pinus clausa clausa*), Outcalt (2003) reported that fire-killed pine snags "are an important structural component for at least a decade following fires." Data are sparse, but consistently indicate at least some beetle-killed trees remain standing 10 years or more after death. Leaving buffers of dead lodgepole around patches of other tree species likely will mitigate windthrow.

- *Small buffers of dead lodgepole pine around retained inclusions of other tree species will help to sustain biodiversity.*

In pure pine stands, retention of small (>0.2 ha) groups of dead pine also will help retain some early seral or generalist species, that might otherwise disappear (e.g., American kestrel, red-tailed hawk, dusky flycatcher, olive-sided flycatcher).

- *Retention of small groups (>0.2 ha) of dead pine will help to retain a portion of early seral and generalist species.*

Some portion of beetle-killed trees should remain standing for at least 10 years (Agee 1981; Bull 1983; Outcalt 2003). During that time, dead lodgepole pine stems and retained stands of other species will help to sustain vertebrates that might otherwise disappear from the area. These groups will be particularly valuable when centered around larger pine, for then they can help sustain cavity-nesters as well.

Among this broad group of species are several that are hunted, trapped or otherwise susceptible to increased access. The approach to salvage operations will determine the degree of road construction. A small patch “snip and skid” approach will create roads and increased access throughout the affected area. Moving in and harvesting larger areas quickly, then deactivating roads, can reduce negative effects. We recommend:

- *Avoid small patch-wise approaches. Plan to harvest larger areas blocks (e.g., up to 1000 ha) quickly and deactivate roads when finished.*

Given the life histories of most vertebrates present, large openings on the scale of 1000 ha should not create negative impacts *provided* that some patches of 10 to 100 ha plus smaller patches are retained (accommodated with the provision of 20% retention when determining the uplift in AAC). Planning harvest over larger blocks can maintain most species and also will reduce road building, thereby mitigating potential negative impacts on fish and some mid to late seral terrestrial species. All benefits are not attained unless roads are subsequently deactivated. A potential corollary to harvesting over larger areas is to leave other larger areas unharvested. Some of these trees will remain standing for at least a decade (references above), and will contribute desired elements of stand structure as they fall. It is unclear what levels of downed wood will accrue and whether or not these will represent an increased fire hazard or disadvantage some species. Current evidence suggests that leaving large areas unharvested is beneficial, particularly for aquatic habitats (Lindenmayer et al. 2004). These blocks also will benefit late seral species (see “Late seral” below). We recommend:

- *Plan both areas to be reserved from harvest and areas to be harvested as large blocks.*

Within this broad group, nine species are “flagged” by various listing processes. The great blue heron and the grizzly are blue-listed by the BC CDC. COSEWIC lists the northern goshawk and peregrine falcon as “threatened” and the western toad and grizzly as of “special concern.” The peregrine falcon (*anatum* subspecies) is red-listed by CDC. The great blue heron and grizzly also appear on the Identified Wildlife 2004 list. Four of the ungulates (elk, mule deer, white-tailed deer and moose) are noted as potentially requiring winter ranges. Listed species are treated separately below.

Shrubs

Within the three TSAs, 35 species (29%) respond positively to shrub cover. Of these species 30 are birds, which nest in or under shrub cover or use shrubs for foraging. The five mammal species favoured by shrub cover include snowshoe hare, elk, moose, mule deer and white-tailed deer. Large-scale salvage logging should encourage shrub cover, though perhaps not beyond that in beetle-killed stands not salvaged, and benefit these species. Of these 35 species, most (32) also are considered habitat generalists or early seral associates. The remaining three are more responsive to the presence of shrub cover than to seral stage. For most of these species, habitat is improved when taller trees are present.

Combining the vertebrate responses to seral stage with vertebrate responses to shrubs, salvage logging might either benefit or have neutral effect on as many as 65% of the species present. That percentage is uncommonly high for forest types and occurs primarily because lodgepole pine is a fire-adapted species, subject to frequent disturbance.

Thus, conducted appropriately,salvage logging can benefit as much as 65% of the resident, terrestrial vertebrate fauna. Because the presence of groups of taller trees (live and dead) increases suitability for both shrub users and their predators, three key attributes of practice are identical to those noted above for early seral associates and generalists. Specifically, large areas can be harvested, provided non-pine species and small groups of dead pine are retained.

To attain optimal response to salvage logging, there is an additional restriction necessary on management practice.

- *Control of minor vegetation should be used sparingly.*

There are no listed species among those showing a strong positive response to shrub cover.

Downed Wood

Eventually, there may be excessive amounts of downed wood in non-salvaged areas of beetle kill – either from the perspective of fire hazard or impeding ungulate movement. Salvage logging could produce considerable amounts of downed wood. This addition might be expected to act as a positive contribution to sustaining vertebrates and other components of biological diversity. The method of salvage logging will determine how much is left in salvaged areas. Commonly the debris is piled and burned, which would then leave salvaged areas depauperate of downed wood.

Within the three TSAs, 27 species (22 of which are mammals) are known to respond positively to additions of downed wood (Appendix I). The river otter may as well. Only six of these species are not early seral associates or generalists. No species showing strong positive associations with downed wood also favours lodgepole pine. Moreover, most of the mammals are larger species (e.g., marten and fisher) that use downed wood for denning sites and require pieces of larger diameter. In their review, Bunnell et al. (1999) suggested that logs of 50 cm diameter would accommodate the mid-size mammals. This value is similar to that of 52 cm, suggested as the lower limit of large logs by DecAID (Marcot et al. 2002). Logs of this size also are likely to retain dry interiors and support other organisms including insects sought by woodpeckers and flickers. Large logs come only from large trees, and will not be provided by lodgepole pine.

The fact that species most tightly associated with downed wood require larger diameters affirms the earlier recommendation:

- *Retain tree species other than lodgepole pine.*

Retention of conifer tree species other than lodgepole pine is particularly important for larger mammals using downed wood as dens. Few lodgepole pine grow large enough to provide den sites for these species. Some of the retained trees eventually will fall and provide den sites for larger mammals and substrate for a variety of bryophytes, lichens and vascular plants. As with early seral associates or generalists and those species responsive to shrubs, the potential gains that may result from salvage logging are foregone when trees other than lodgepole pine also are harvested. That is, while these recommendations consider the potential gains that can derive from salvage logging, failure to implement them can increase the losses.

New guidelines for coarse woody debris are being developed. They apply equally to salvage operations. Downed wood is most effective at sustaining biodiversity when diameters are over 30 cm and the distribution is neither completely aggregated (piled) nor completely uniform (Bunnell et al. 1999; 2002*a*,*b*). However, the smaller mammals and some birds that are expected to be sustained in salvaged logged areas (early seral associates or habitat generalists) will respond to positively to pieces 15 cm or more in diameter. Larger pieces (>15 cm) also will contribute to sustaining mycorrhizal fungi and other small organisms as well as smaller vertebrates We recommend:

- *Leave any slash >15 cm in diameter where it lies.*

Two species within this group appear on lists intended to flag species of concern. The fisher often uses downed wood as dens and is red-listed by the CDC. The wolverine makes opportunistic use of downed wood and is listed as of "special concern" by COSEWIC and blue-listed by the CDC. Both species use larger diameters of downed wood that can be provided by lodgepole pine (reviews in Bunnell et al. 1997, 1999 and Marcot et al. 2002).

Minimizing anticipated negative responses

Riparian

In all forest types, many species are statistically more abundant or productive in riparian areas. Within the three TSAs, 92 of 182 species (50.5%) are more abundant or productive within riparian areas. There are as many late-seral associates (22) as early seral associates (20) among species that prefer riparian areas. As noted in sections below, appropriate riparian management will do much to mitigate potential negative effects on many species strongly dependent on deciduous trees, cavity sites, and late seral stages. Moreover, 63% of early seral and generalist species are riparian associates. Avoiding the harvest of riparian areas is critical to mitigating negative responses on a wide range of species.

- *Follow former Forest Practice Code guidelines when harvesting near streams and rivers.*

Following those guidelines will itself help to maintain a diversity of tree species.

Six species of riparian associates are listed as "at risk." The British Columbia CDC has blue-listed the great blue heron, grizzly bear, and northern population of the woodland caribou, and red-listed the peregrine falcon (*anatum* subspecies), fisher and the southern population of the woodland caribou.[1] COSEWIC lists the peregrine falcon and some herds of both northern and southern caribou populations as "threatened." The grizzly is listed as of "special concern." Three riparian associates occur on the 2004 provincial list of "Identified Wildlife" – great blue heron, grizzly bear and caribou. An additional three species are included in the category of ungulate species for which winter range may be required – white-tailed deer, elk, and moose. (See "Listed species" below.)

Hardwood trees and stands

A total of 45 vertebrate species within the three TSAs show marked preferences for hardwood trees or stands. Most of these (32) are birds. Of the 45 species, 31 (69%) also show marked preferences for riparian areas where hardwoods are more abundant. The other 14 species use primarily upland hardwoods away from riparian areas, but often will be found in riparian areas as well. A few cavity-nesting birds seek areas that are predominantly hardwood (e.g., most of the cavity-nesting waterfowl, northern flicker, red-breasted sapsucker, black-capped chickadee). Even where hardwoods occur sparingly, most primary excavators (that excavate holes used by themselves and subsequently by other species) seek out hardwood trees as nesting sites (Table 1).[2]   Hardwoods are sought because they frequently incur heart rot while still maintaining a sound external shell.

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[1] Both northern and southern populations (northern and mountain ecotypes) occur in the area of the three TSAs.

[2] The harlequin duck. brown creeper, winter wren and house wren use cavities only rarely, and usually rely on ground nests, undercut riverbanks, root wads of fallen trees, or crevices in the bark.

Although there are 32 cavity-nesting birds within the area, only six are large, strong primary excavators capable of excavating holes that other bird, bat and other small mammal species use. Of those six, five preferentially excavate in hardwood species (the exception is the pileated woodpecker; Table 1). These large primary excavators are sometimes referred to as keystone species, because so many other species depend upon the holes they excavate, including rodents and bats. In the three TSAs, these keystone species (and thus those dependent upon them) rely largely on hardwood trees as nest sites. That alone makes the maintenance of hardwood components critical to sustaining biological diversity. The presence of hardwoods or deciduous species also benefits other organisms, such as fungi (Fernando et al. 1999), lichens (Goward 1999; Goward et al. 1994), bryophytes (Vitt et al. 1988), and invertebrates (Berg et al. 1994). Provision of riparian buffers will accommodate many of these species, but if deciduous trees become restricted only to riparian sites, the abundance of these species and the secondary cavity nesters dependent on them will be reduced. Moreover, at least 13 species seek upland hardwoods away from water. Preference for deciduous or hardwood cover also is expressed by mammals, including 10 mammal species within the study area.

In short, reservation of riparian areas and upland hardwoods from harvest is critical. Their reservation will help to maintain many other species of lichens, bryophytes and invertebrates. This broad array of species likely will be maintained provided salvage practices:

- *Reserve riparian and upland hardwoods from harvest.*

Cavity Sites

A total of 47 terrestrial vertebrate species within the three TSAs use cavities for nesting or denning sites. One of these species is red-listed in British Columbia (fisher). Farther south, the grizzly (listed as of "special concern" by COSEWIC) sometimes dens in trees, but tree dens are unlikely to be prevalent in the TSAs. Of the 47 species, 32 are birds and 15 are mammals. All but four of the bird species require cavities.[2] Some of the smaller mammals rely almost exclusively on cavities for maternal dens (e.g., big brown bat, hoary bat), while use by larger mammals is more opportunistic (e.g., porcupine, black bear). Fisher and American marten, however, appear to require large cavities. Only three of the cavity-using species commonly use lodgepole pine for cavity sites. The black-backed woodpecker often uses lodgepole pine (Table 1), primarily because it responds strongly to insect outbreaks and nests near its food source. The northern flying squirrel and red squirrel also use lodgepole pine frequently. We found no records of use of lodgepole pine as denning sites by any of the seven bat species present in the area.

As noted above, hardwood trees are favoured cavity sites for birds and bats (Table 1). Moreover, the six strong primary excavators, five of which prefer hardwoods, create most of the cavities for the smaller species. That fact emphasizes the importance of retaining hardwoods in both riparian and upland sites.

Salvage logging likely will be concentrated in the oldest pine classes, which are the only stages capable of providing cavity sites. As well as retaining cavity sites in snags and living trees, it is possible to create cavity sites during salvage operations. In the Boundary Forest District, Pope and Talbot conducted a 125-ha salvage cut after mountain pine beetle attack. All of the Douglas-fir and western larch were reserved from harvest and about 170 "stubs" were created from lodgepole pine. The stubs were created by feller buncher, and were 3-5 m tall and mostly between 25 and 35 cm DBH (Harris 2001). Though stubs ranged from 9 to 43 cm DBH, the large majority of nests were established in stubs over 35 cm. Harris (2001) reported on use of stubs by cavity-nesting birds over a 10-year period. A total of 86 active nests were observed over 10 years. Of these, 52 were identified as being used by eight different species of cavity-nesting birds. All of these species occur within the three TSAs: northern flicker (22 nests); mountain and western bluebirds (18), hairy woodpecker (4), tree swallow (3), American kestrel (2), mountain chickadee (1); and red-breasted nuthatch (1).

Harris (2001) made three observations that can help to fully exploit the potential of creating stubs to sustain cavity-nesting birds. First, 95% of the nests were created in the area clearcut of pine, leaving only the stubs. Second, the large majority of nests were created in snags over 35 cm DBH. Third, all nesting occurred in “reworked” holes already present at the time the stubs were created. Combined, these observations suggest that:

- *Tall stumps or stubs as cavity sites should be created where other tree species have not been reserved from harvest and harvest method permits.*

- *Stubs should be restricted to trees >30 cm in DBH or where cavities already exist.*

Table 1. Percent of cavity sites in lodgepole pine and in hardwoods for cavity-nesting bird species present in the three Timber Supply Areas.[1]

Species	N[2]	Percent in lodgepole	Percent in Hardwoods[3]	Seral Stage[4]
Barrow's Goldeneye	44	2	43.2	G
Bufflehead	228	3	60.1	G
Harlequin Duck	31	0	0	G
Common Goldeneye	17	0	58.8	G
Common Merganser	53	0	39.6	G
Hooded Merganser	38	0	57.9	G
American Kestrel	261	0	29.9	G
Barred Owl	8	0	50.0	M-L
Northern Hawk Owl	3	0	0	L
Northern Pygmy-Owl	5	0	0	M-L
Northern Saw-whet Owl	31	0	51.6	M-L
Vaux’s Swift	13	0	0	L
Black-backed Woodpecker	81	71.4	0.8	L
Downy Woodpecker	105	0	81.3	L
Hairy Woodpecker	346	16.9	39.4	L
Northern Flicker	998	9.9	44.7	G
Pileated Woodpecker	199	0	25.0	L
Red-breasted Sapsucker	284	0	22.2	M-L
Three-toed Woodpecker	81	20.3	79.8	L
Yellow-bellied Sapsucker	107	0	89.6	L
Black-capped Chickadee	109	0	87.5	G
Boreal Chickadee	18	0	56.0	L
Brown Creeper	30	1	30	L
House Wren	942	0	7	G
Mountain Bluebird	2728	0	--	G
Mountain Chickadee	206	0	55	L
Pacific-slope Flycatcher	154	0	>25	L
Red-breasted Nuthatch	275	2.3	31.3	L
Tree Swallow	2745	0	--	E
Violet-green Swallow	515	0	--	E
White-breasted Nuthatch	28	22.2	11	L
Winter Wren	122	0	--	G

[1] The harlequin duck. brown creeper, winter wren and house wren use cavities only rarely.
[2] Total number of nests from which percent calculated.
[3] -- Indicates insufficient data to calculate percent of nests in hardwoods.
[4] G = generalist with respect to seral stage, M-L = mid to late successional stages, L = largely restricted to late seral stages.
Sources include: Bunnell et al. (2002*c*), sources therein, and Campbell et al. 1990*a*.

Tree species other than lodgepole pine are preferred as nesting sites (Table 1), so it is important to retain other species during salvage harvest. The finding of Harris that most nests were in the clearcut and "stubbed" lodgepole pine area appears anomalous and may be explained by the condition of the Douglas-fir and western larch left in the selectively logged areas (which was not reported). The use of stubs does confirm that cavity nesters will use sites almost completely harvested provided some nest sites are left. Examining stands before harvest would permit marking candidate trees for stubbing that already had woodpecker holes. However, using 30 cm DBH as a guideline is likely a useful surrogate for selection. Above that diameter, lodgepole pine often is experiencing heart rot and providing suitable cavity sites. Moreover, Bull (1983) reported that snags less than 25 cm DBH were not used by cavity nesters and do not stand for very long because of windthrow.

Harris (2001) noted that stubs that were sound at time of cutting were still standing 10 years later. He also reported a rancher noting that when a rooted lodgepole pine tree was cut at fence height to support a fence, it would need replacing after about 15 years. These observations suggest that stubbed lodgepole pine will provide nest sites for 10 to 15 years and confirm the utility of leaving even dead lodgepole pine to sustain other values.

Late seral
Our review (Appendix I) suggests that 56 of the species present within the three TSAs favour late seral stages. These include 39 birds and 17 mammals. Many of these (29) require late seral stages largely because they require cavity sites in trees large enough to provide habitable cavities. Lodgepole pine rarely attains that size. Moreover, lodgepole pine simply does not live long enough to produce the attributes normally considered to characterize old growth (e.g., Franklin and Spies 1991; Marcot et al. 1991; Wells et al. 1998; Braumandl and Holt 2000). In his review, Agee (1993: 349) reported that "Climax lodgepole pine stands rarely grow more than a century without a major disturbance by fire or insects." Other than some caribou during winter, we know of no vertebrate, lichen or bryophyte that is more abundant in older lodgepole pine stands than in other forest types. Black-backed woodpeckers and three-toed woodpeckers can be exceptions during bark beetle outbreak, which may be their favoured habitat. These observations suggest that for most of the 56 late seral species in the area, lodgepole pine is not a major component of their habitat.

The potential exceptions to this generalization are those species that prefer large, contiguous tracts of forest or "forest interior" species. Where lodgepole pine is well intermixed with other species, the pine contributes to the "interior" nature of the habitat. There are 11 species within the three TSAs that have been considered "forest interior" species, of which two are mammals (Appendix 1). The two mammals are either red-listed (fisher and some caribou populations) or blue-listed (other caribou populations) by the CDC. The caribou populations are considered either "threatened" or of "special concern" by COSEWIC. Caribou is listed within "Identified Wildlife 2004" and is a designated ungulate for which winter ranges may be required.

Removal of 40% or more of the forest cover over large areas likely will impact "interior" species negatively, even where riparian areas and other tree species are not harvested. Most of these species do not find lodgepole pine suitable habitat (caribou is an exception), but do seek out continuous canopy. Leaving larger areas unharvested where lodgepole pine is well intermixed, and represents less than 40% of the species mix, should maintain "interior" habitat. The pine will fall, but some will remain standing at least 10 years – time for regeneration to occur. For this approach to be effective, large areas such as small watersheds should be left unharvested. That has the additional benefit of reducing road building and its associated negative impacts. Locations of susceptible fish species could be used to guide which areas were selected (see "Impacts of logging on fish"). An obvious consideration is elevating the fire hazard rating through accumulation of fuels (though economic risk may decline as dead trees lose their value). There is no unequivocal way to evaluate tradeoffs between sustaining susceptible aquatic and terrestrial vertebrates and potential increases in fire hazard. We do know that not retaining some relatively intact areas will negatively impact some species, and therefore recommend:

- *Avoid salvage in selected areas where intermixed pine represents <40% of the species mix.*

Specific recommendations for caribou winter range follow under “Listed species.” Further relevance of large unharvested areas is discussed under “Freshwater Fish.”

Listed species – forest-dwelling terrestrial vertebrates

Among the 182 species present within the area currently planned for large-scale salvage operations, 11 appear on “at risk” lists or are ungulates requiring management for winter range. Comments are presented for each of these separately.

Western toad: “Special concern” by COSEWIC. COSEWIC considers there to be two primary threats to the western toad: 1) stocking of lakes where fish do not occur naturally, and 2) loss of wetlands due to urban development and agriculture. Neither of these threats will be exacerbated by large-scale salvage operations. Large-scale removal of forest cover may expose the toad to drier conditions, but it is more resistant to desiccation than most amphibians. Provided other tree species are reserved from harvest and riparian areas are not harvested, there should be little impact.

Great blue heron: Blue-listed by the CDC; Identified Wildlife 2004. Threats to heron populations are diverse. Population threats include: disturbance and mortality from predators and humans (e.g., fish farms), limitations to food supply and biocide contamination. Habitat threats include: urban development, hydroelectric development and forestry. Threats from forestry are primarily the removal of current and potential nest trees. Lodgepole pine has not been reported as a nest tree; black cottonwood frequently is used at inland sites. Provided that riparian areas are left unharvested and species other than lodgepole pine are retained, large-scale salvage should have little impact on the heron. It is, however, possible that increases in the rate of cut could alter aquatic environments sufficiently that food becomes less abundant (see “Freshwater fish” below).

Northern goshawk: the *laingi* subspecies restricted to the coast is considered “threatened” by COSEWIC. Although somewhat nomadic, it is unlikely to enter the TSAs for sustained periods. COSEWIC considers the threat to goshawk to be logging of low-elevation, old growth coniferous forest and suitable second-growth forest. Lodgepole pine is not a favoured habitat of the goshawk. Provided other tree species are reserved from harvest it should not be impacted by large-scale salvage operations. Prey-response to increased early seral stage may benefit the species.

Peregrine falcon (*anatum* subspecies): “threatened” by COSEWIC; red-listed by the CDC. The falcon is a spring migrant through central British Columbia with little evidence of breeding in the study area. Subspecies *anatum* formerly bred in the Okanagan and in the drainages of the Fraser and Peace rivers (Campbell et al. 1990*b*; Fraser et al. 1999), and perhaps the east Kootenays (Cooper 1998). The current known range of the species is concentrated in the southwest mainland and Gulf Islands/southern Vancouver Island region, with a few local breeding pairs in the south and central interior (Fraser et al. 1999). Almost all peregrine falcon nests are found in cliffs. Of 305 nests, 5 were found in abandoned nests of bald eagles and common ravens (Campbell et al. 1990*b*). Nesting sites have been abandoned because of disturbance caused by human activities such as road construction below nesting cliffs (Fraser et al. 1999). Given the bird’s rarity in the area, local personnel of the British Columbia Ministry of Water, Land and Air Protection should know of any potential locations. Major construction should not be undertaken within 200 m of any nest site, from March 15 through June 30. Use of tree nests is rare, and provided other tree species are reserved from harvest the species should not be impacted by large-scale salvage operations.

Fisher: red-listed by the CDC. The fisher occurs at low density throughout central and northeast British Columbia, and the area it occupies within this range appears low (Weir 2003). Fishers are found in forested landscapes with mesic, dense, late-successional coniferous or mixedwood forest. They prefer forests with high structural complexity with components such as large trees, canopy gaps and associated understory vegetation, snags, downed wood and limbs near the ground (Buskirk and Powell 1994; Powell and Zielinski 1994; Zielinksi et al. 2004). They tend to avoid open areas with no understory or shrubs and usually require forest habitat with at least 30% canopy closure for movement (Buskirk and Powell 1994). In California, fishers have been reported from higher-elevation habitats of mixed red fir-lodgepole pine forest (Buck et al. 1983). In British Columbia, fishers are known to prefer structurally complex and mesic riparian forests. Females prefer to den in large-diameter black cottonwood or balsam poplar trees (Weir 2003).

Forestry practices negatively affect fisher habitat in several ways. Habitat is lost due to logging of old forests and removal of larger-diameter trees, particularly from riparian sites – both streams and wetlands; creation of large openings and habitat fragmentation may restrict movement; lack of structural complexity in recently logged stands makes habitat less favourable; and increased access for trappers results in increased mortality (Cannings et al. 1999; Powell and Zielinski 1994; Thompson and Harestad 1994; Weir 2003). It is difficult to separate potential impacts, but increased trapping mortality appears to have the greatest effect (review in Bunnell et al. 1997). Fisher are unlikely to use large salvage blocks even where other tree species are retained. Still, reserving riparian habitat and non-pine species from harvest will permit more rapid recolonization of salvaged areas. Following the general recommendation for “forest interior” would benefit the fisher by attaining greater forest continuity, increasing structural complexity and sustaining den sites. Because the fisher appears particularly susceptible to trapping, deactivation of roads is important (Bunnell et al. 1997). Although it likely will be negatively impacted by large-scale salvage operations, the fisher would be expensive to monitor.

Grizzly bear: “special concern” by COSEWIC; blue-listed by the CDC; identified Wildlife 2004. The grizzly’s former range in North America has decreased greatly due to agriculture and urbanization. It is now confined mostly to Alaska and northwestern Canada. The species occurs throughout much of British Columbia, but is absent from the south central and southern regions where it has been extirpated (BCMOF 1997). The grizzly often inhabits alpine and subalpine areas with grasslands, shrublands, meadows, forests, and alpine communities (Saxena and Bilyk 2000). Avalanche slopes, subalpine meadows, valley bottoms, riparian zones, burned areas, and cutblocks provide foraging across the landscape. Optimal habitat consists of open areas for feeding with adjacent forested areas for cover (Heinrich et al. 1996). Direct killing by humans is the major mortality factor (McLellan et al. 2001). Currently, grizzly bears have become more restricted to mountainous terrain because of severe alteration of the landscape and excessive mortality at lower elevations.

Forest practices can increase mortality indirectly– through road construction that increases access by hunters or poachers. Practices that increase berry production (e.g., clearcutting) can be beneficial where food is limiting. Provided hunting and poaching access is not greatly increased the net effect of salvage operations on grizzly bears may be positive. As for fisher, caribou, other larger mammals and fish, it is important that new roads be deactivated quickly.

Wolverine: “special concern” by the CDC; blue-listed by the CDC; identified Wildlife 2004. The wolverine is absent from north coastal areas, but occurs in low numbers throughout much of the rest of the province. The red-listed subspecies, *vancouverensis*, which occurred on Vancouver Island may now be extirpated.

In northern British Columbia, the wolverine is found at higher elevations during the breeding and summer seasons (in the ESSF and AT zones). The ESSF zone is used more for denning than the alpine tundra (Krebs and Lewis 2000). Lower-elevation habitat in the SBS and BWBS is frequented at all other times of the year (Lofroth et al. 2000). Wolverine movements depend primarily on food availability. Large herbivore carrion is an important food source and wolverine are partly dependent on the abundance of ungulates and predators to provide carrion. There are few data on specific habitat requirements, but in general, they tend to be more abundant in landscapes where habitat diversity and prey abundance are high (Banci 1994). Forestry practices may negatively impact wolverine by increasing direct mortality from hunting and trapping (e.g., Krebs et al. 2004) and by causing declines in food species such as caribou. Overall, little data exist on forestry impacts on wolverine (Banci 1994; Bunnell et al. 1997). Although wolverine may once have ranged more widely, much of their present habitat is currently inoperable. If large-scale salvage operations have the effect of reducing ungulate numbers (unlikely in most areas), the wolverine could be negatively impacted. Its relative rarity makes it a difficult species to monitor and it would be easier to monitor its major food sources.

Elk: a designated ungulate for which an ungulate winter range may be required. Rocky Mountain elk are locally abundant but not widespread within the study area. Elk are generalist herbivores, both grazing and browsing, with a high degree of dietary flexibility. Preferred feeding sites are a mix of open grasslands and shrub lands, and open mixed coniferous and deciduous forests (Shackleton 1999). They seek forested habitats when resting. For these reasons we considered elk a habitat generalist with respect to stand age (Appendix I) and believe that if the recommendations offered above for habitat generalists are implemented, elk are likely to benefit from salvage logging. The possible exception is during winters of deep, prolonged snowfall. Where known winter ranges occur within lodgepole pine, we recommend salvage logging only half of the range. Leaving dead trees maintains some thermal, snow and security cover while permitting understory growth and also reduces potential negative effects of access.

Moose: a designated ungulate for which an ungulate winter range may be required. Shackleton (1999) reported moose to be abundant to plentiful through most of the study area. Their diet consists primarily of shrubs and young trees, particularly deciduous species, that occur more abundantly on recently disturbed sites. Salvage logging should provide greater amounts of forage. As with other ungulates, winter is the time of greatest stress when moose seek out riparian areas or stands of dense conifers. Because of their stature, moose are able to cope with deeper snow. Provided that riparian areas and trees other than lodgepole pine are left unharvested, salvage logging should have few negative impacts on moose.

Mule-deer: a designated ungulate for which an ungulate winter range may be required. Shackleton (1999) reported mule deer to be moderate to few through most of the study area, with localized areas designated “plentiful” at the southern edge. The species generally is more abundant to the south and to the northeast in the Peace River lowlands. Like the elk, the Rocky Mountain mule deer (the subspecies present in the area) is a generalist herbivore, both grazing and browsing. They do best in open forested areas or parklands with adjacent grasslands, but also inhabit drier timbered slopes and river breaks. They commonly forage in more open areas and rest under tree canopy. Provided that riparian areas and trees other than lodgepole pine are left unharvested, salvage logging should have few negative impacts on mule deer. The possible exception is during winters of deep, prolonged snowfall. Where known winter ranges occur within lodgepole pine, we recommend salvage logging only half of the range. Leaving dead trees maintains some thermal, snow and security cover while permitting understory growth and also reduces potential negative effects of access.

White-tailed deer: a designated ungulate for which an ungulate winter range may be required. White-tailed deer have a localized distribution within the study area, centred broadly around Prince George. In this area Shackleton (1999) characterized their abundance as “few.” White-tails prefer heavily vegetated cover, such as riparian areas or other extensive shrubby areas. During darkness they will venture into open areas, including agricultural fields, to forage. Provided riparian areas are reserved from harvest there should be no negative effects of large-scale salvage logging on white-tailed deer.

Woodland caribou: the northern population of woodland caribou is considered “threatened” or of “special concern” by COSEWIC, and is blue-listed by the CDC; the southern population is considered “threatened” by COSEWIC and red-listed by the CDC. The woodland caribou is an Identified Wildlife Species (2004) in British Columbia, and a designated ungulate for which an ungulate winter range may be required. The common names that COSEWIC applies to caribou are potentially confusing, given their actual range. It is more helpful to view the two groups as the northern ecotype and mountain ecotype.

The northern ecotype (northern woodland caribou) occurs in the mountains of western and northern British Columbia. It is by far the most abundant population in British Columbia, numbering about 16,000 individuals (Heard and Vagt 1998). The population has been extirpated from most of the Quesnel TSA. The Itcha-Ilgachuz herd remains at the western portion of the TSA. Distribution of the Tweedsmuir herd overlaps with the southwest extremity of Vanderhoof Forest District. “Northern” caribou migrate to low elevations in winter, where they feed on terrestrial and arboreal lichens, but spend spring and summer at high elevations. Some caribou remain at high elevations in winter at windswept, exposed areas where the ground is bare (Shackleton 1999). Some winter ranges consist of terrestrial lichens underneath a canopy cover of lodgepole pine. Without a substantial snow pack, moving machinery across the lichen mats will disrupt them and reduce important winter forage. Lichen dispersal, establishment and growth are slow and it may take decades before the quantity of terrestrial lichen within a clearcut is comparable to that in old stands. Moreover, where undamaged by machinery, it is unclear what the effects on the lichen mats will be, but in Finland opening the canopy changes species composition (Bunnell et al. 1973). Where understory shrubs respond positively to the opening of the canopy they will suppress the growth of ground lichens.

The global range of the mountain ecotype (southern woodland caribou) is found almost entirely in British Columbia (98%), totaling less than 1900 individuals in 13 herds. This ecotype ranges from the Hart mountain range south of Chetwynd into the northern United States. Herds of the “southern” population occur in the eastern portion of the Quesnel TSA, mostly in Bowron Lake Park. Most herds of the mountain ecotype make four elevational migrations each year. In early winter, they use low elevations and forage on arboreal lichens and shrubs. High conifer canopy is important to prevent snow build-up over food sources. Once the snow has compacted and hardened in late winter, they move up to mature and old subalpine forests where they feed almost exclusively on arboreal lichens (*Bryoria* spp.). Spring and summer are spent at lower elevations except for calving which occurs in high elevations (Apps et al. 2001; Simpson et al. 1997; Stevenson et al. 2001).

The main threat to woodland caribou appears to be loss of older forests over a large area (Stevenson et al. 2001). Caribou tend to avoid early seral areas, particularly in winter when they forage on ground or arboreal lichens found in older forests. Logging of older forest over a large area removes an important winter food source for caribou (lichens), and subsequently concentrates these animals into smaller areas of suitable habitat, making them more prone to predation. Clearcutting, which can create foraging habitat favourable to other ungulate species (e.g., moose and mule deer), simultaneously reduces forage for caribou while increasing predation of caribou. Caribou are particularly susceptible to wolf predation because they have relatively low reproductive rates and do not use escape terrain as do other ungulates with low reproductive rates (e.g., mountain goats and sheep). A wolf population may be able to eliminate a caribou population over time while maintaining or increasing their own population due to an adequate food source from other ungulate species (Kinley and Apps 2001; Seip and Cichowski 1996; Seip 1992).

The provisions for AAC uplift recognize that that there are special caribou management areas within the TSAs. If caribou are to be maintained, it appears that the best approach is to avoid salvage logging on at least half of designated winter ranges. Clearcutting of lodgepole stands where caribou forage on terrestrial lichens is likely to be particularly detrimental by increasing snow depth and decreasing access to lichens, damaging the lichen mat, and favouring shrub growth over lichen growth. In the short term, caribou continue to use dead pine stands to forage (D. Seip, British Columbia Ministry of Forests, pers. comm.). Deadfall may eventually prohibit caribou access to the area. If the lichen mat is damaged it will take decades to recover in that portion of the winter range that has been salvage logged, but the reserved portion will help to sustain caribou during the interim. We concur with the British Columbia Forest Service recommendation:

- *Reserve half of each known lodgepole pine ungulate winter range from salvage.*

The other major recommendation that derives from consideration of listed species is:

- *Get in and out of salvage areas quickly, and deactivate new roads wherever possible.*

Reducing the period of active logging in an area reduces the period of potential disturbance. Several listed species are liable to experience negative effects with increased access, so new roads should be deactivated.

Freshwater fish

A total of 29 species of freshwater fish are found in the Lakes, Quesnel, and Prince George TSAs. Seven of these are listed as “at risk” by either the CDC or COSEWIC. Only four species have been assessed by COSEWIC, two of these as “not-at-risk” (Table 2). The Interior Fraser River population of the yellow-listed coho salmon (*Oncorhynchus kisutch*) is listed as *endangered* by COSEWIC, but is not recognized by the CDC. The Nechako and upper and lower Fraser River populations of the white sturgeon (*Acipenser transmontanus*) are red-listed by the CDC and are listed as endangered by COSEWIC. The Williston Watershed population of the yellow-listed arctic grayling (*Thymallus arcticus*) is red-listed by the CDC, because it is isolated by the W.A.C. Bennett Dam and has been declining in the past 20 years. The “coastal” sub-species of the cutthroat trout (*Oncorhynchus clarki clarki*) is blue-listed by the CDC. The chiselmouth is blue-listed by the CDC because its populations appear to be disjunct and relictual, and because it may have been extirpated in some places within the province. Two other species, the bull trout (*Salvelinus confluentus*) and the Dolly Varden (*Salvelinus malma*), are blue-listed by the CDC while the remaining 22 species are yellow-listed by the CDC. The bull trout is also listed under the Identified Wildlife Management Strategy.

Because they are confined to water, freshwater fish populations are more constrained and isolated than are most terrestrial vertebrates. Existing range is less flexible than for many terrestrial vertebrates. We considered two criteria to describe the conservation concern for fish within the three TSAs. The first is stewardship responsibility, measured by the proportion of global range that occurs within the province and the TSAs; the second is the likely response to salvage logging, given life history traits. More than half (18) of the freshwater fish in the Lakes, Quesnel, and Prince George TSAs are of high provincial stewardship responsibility because more than 30% of their global range or population is found in British Columbia (Bunnell et al. 2004a,b). In particular, at least half of the global range of four species is found in the province: peamouth (*Mylocheilus caurinus*), pygmy whitefish (*Prosopium coulteri*), prickly sculpin (*Cottus asper*), and the breeding range of the sockeye salmon (*Oncorhynchus nerka*). Three of these 18 species of high provincial stewardship responsibility also are of high stewardship responsibility for one or all of the TSAs. A significant portion of the global range of the pygmy whitefish is found in the study area. All or most of the red-listed, endangered Nechako River and Upper Fraser River populations of the white sturgeon are found in the Prince George TSA. Most of a potentially disjunct population of the chiselmouth is found in the Quesnel TSA. The remaining 11 species are wide-ranging or “peripheral” – less than 10% of their global ranges extend over more than a third of the province.

Methodology used to assess sensitivity to salvage logging is discussed under “Impacts of logging on fish.” Applying that methodology, 11 species (10 of 13 salmonids and the burbot, *Lota lota*) are the most likely to be negatively impacted by large-scale salvage logging (Table 2). The sensitivity of four of these was rated “very high” – cutthroat trout, coho salmon, bull trout, and Dolly Varden. Because 30-50% of the global range of these four species is found in the province, these also are ranked as having very high conservation concern. Three other species (chiselmouth, brassy minnow, and pygmy whitefish) have been ranked as having very high conservation concern because their populations in the province are disjunct, and thus may have evolved into new forms or may evolve in the future. Because the pygmy whitefish is not only disjunct with a localized distribution within the study area and of high stewardship responsibility, but also is likely to be negatively impacted by salvage logging, this species is of highest conservation concern of all 29 species. One other species, the leopard dace (*Rhinichthys falcatus*), is rated of low conservation concern due to its relative insensitivity to salvage logging. However, it has been identified as at risk from forestry by other authors (Haas 1998), and the study area comprises a significant portion of its global range.

Three of the 11 species (burbot, lake trout, *Salvelinus namaycush,* and lake whitefish, *Coregonus clupeaformis*), though likely to be negatively impacted by salvage logging, are globally and provincially widespread with only a small portion of their global range in the province (<10%). Thus, these are of moderate conservation concern. The remaining three species (arctic grayling, mountain whitefish, *Prosopium williamsoni*, and rainbow trout, *Oncorhynchus mykiss*) are ranked of higher conservation concern because the province has moderate to very high stewardship responsibility for the species (mountain whitefish, rainbow trout) or for a population (Williston Watershed, arctic grayling).

Impacts of logging on fish

Forest practices impact freshwater fish through modification of freshwater environments. The overall response of fish to forestry-induced habitat changes is a result of interactions between beneficial and adverse effects. The same change in habitat can result in adverse effects on one life-stage, beneficial effects on another, or both on the same life stage. For example, removal of riparian vegetation can result in increased primary production, increased invertebrate biomass, and thus increased food availability to adult insectivores. However, subsequent increases in adult growth rates in the short-term may coincide with higher incidence of adult diseases over the longer term if stream temperatures rise above tolerable levels. Higher temperatures may reduce egg survival, which also may be further reduced by sedimentation from stream bank erosion. Effects can be expected to vary even between closely related species. For example, small increases in stream temperatures after removal of riparian vegetation may result in the earlier emergence of fry, which might be beneficial for summer-emerging species like the rainbow trout, but harmful for spring-emerging species like the sockeye salmon in central British Columbia (Hinch 2000). Most forestry impacts on fish populations are derived from studies of salmonids. Non-salmonid species, which comprise about half of the species present in the study area, are less studied and more poorly understood.

Despite the complexity of fish-forestry interactions, generalized negative responses have been summarized from the literature and used to predict relative sensitivities to the changes typically induced by forestry (Table 2). Life history traits used to evaluate sensitivity to logging follow Porter et al. (2000) and are summarized in Table 3. We assumed that the impacts of large-scale salvage logging on aquatic systems are not different from the impacts of large-scale clearcutting of live trees. Further, we assumed that alteration to small creeks and headwaters, increased water yields, and sedimentation are the major impacts of large-scale salvage logging. Life history traits related to these three impacts are used to rank sensitivity to salvage logging. Finally, it is assumed that post-logging temperature changes and depletion of coarse woody debris will be greatest in small streams, especially if these are not buffered. Thus, temperature-sensitivity and dependence on coarse woody debris for species that spawn or rear in small streams are also considered to represent sensitivity to salvage logging (shaded extensions to the right in Table 2).

Major changes that result in negative effects to fish include more barriers to movement by increased debris or poorly installed culverts, increased sedimentation, loss of coarse woody debris , changes in primary productivity, increased water temperature, and the amount and rate of water flow (peak flows in particular). Each change has variable effects on all four stages of the fish lifecycle: egg, fry, juvenile and adult. Responses to forestry are not limited to interactions of habitat change with life history traits. For example, populations of recreational species may be tolerant to loss of some spawning habitat due to forestry-related sedimentation. However, increased access by anglers due to forestry roads can have rapid and severe effects on populations (Gunn and Sein 2000). As well, species with limited ranges are more vulnerable to changes in land-use, regardless of their inherent sensitivities. Most extinct North American fish were species with small geographical distributions (Miller et al. 1989).

Major factors governing the sensitivity of fish to salvage logging are treated individually below. Much of that discussion is summarized from Haas (1998), Miller et al. (1997) and Porter et al. (2000). Other references are found in accounts for individual species.

Table 2. Relative sensitivity to forest practices according to life history traits of fish species that occur throughout the Quesnel, Lakes and Prince George Timber Supply Areas (adapted from Porter et al. 2000 and Bunnell et al. 2004a,b).[1]

Common Name	Scientific Name	BC Status	COSEWIC	Stewardship	Spawning Habitat	Juvenile Habitat	Fall Spawning	Benthic	Gravel	Feeding	Oxygen	Turbidity	Temperature	CWD	k-Selected	Movements	Sensitivity general	Sensitivity salvage	Conservation Concern	
Lake Chub	*Couesius plumbeus*	Yellow	-	L2					x	x				x			L	L	1	LOW
Longnose Sucker	*Catostomus catostomus*	Yellow	-	L2					x		x		x		x		M	L	1	
White Sucker	*Catostomus commersoni*	Yellow	-	L2					x						x		L	L	1	
Largescale Sucker	*Catostomus macrocheilus*	Yellow	-	H1					x						x		L	L	2	
Bridgelip Sucker	*Catostomus columbianus*	Yellow	-	H1					x								L	L	2	
Leopard Dace	*Rhinichthys falcatus*	Yellow	NaR	H1				x	x								L	L	2	
Longnose Dace	*Rhinichthys cataractae*	Yellow	-	L2				x	x	x		x					M	M	3	
Pink Salmon	*Oncorhynchus gorbuscha*	Yellow	-	L2[a]			x				x	x	x				L	M	3	
Slimy Sculpin	*Cottus cognatus*	Yellow	-	L2				x		x		x	x				M	M	3	
White Sturgeon	*Acipenser transmontanus*	Red[b]	E[c]	H1, H3[d]					x						x		L	L	4	MODERATE
Burbot	*Lota lota*	Yellow	-	L2			x		x	x	x	x	x	x	x		H	H	4	
Lake Trout	*Salvelinus namaycush*	Yellow	-	L2			x		x	x	x	x	x	x	x		H	H	4	
Lake Whitefish	*Coregonus clupeaformis*	Yellow	-	L2			x		x	x	x	x	x	x			H	H	4	
Redside Shiner	*Richardsonius balteatus*	Yellow	-	H1					x	x		x					L	M	5	
Northern Pikeminnow	*Ptychocheilus oregonensis*	Yellow	-	H1					x	x		x					L	M	5	
Chinook Salmon	*Oncorhynchus tshawytscha*	Yellow	-	H1			x			x	x	x	x	x	x	x	H	M	5	
Arctic Grayling	*Thymallus arcticus*	Yellow, Red[e]	-	L2, H3[e]	x				x	x	x	x	x			x	H	H	6	HIGH
Peamouth	*Mylocheilus caurinus*	Yellow	-	H2					x	x		x					L	M	6	
Sockeye Salmon	*Oncorhynchus nerka*	Yellow	-	H2			x			x	x	x	x			x	M	M	6	
Prickly Sculpin	*Cottus asper*	Yellow	-	H2				x		x		x					L	M	6	
Mountain Whitefish	*Prosopium williamsoni*	Yellow	-	H1			x		x	x	x	x	x	x		x	H	H	7	
Rainbow Trout	*Oncorhynchus mykiss*	Yellow	-	H1	x					x	x	x	x	x			M	H	7	
Coastal Cutthroat Trout	*Oncorhynchus clarki clarki*	Blue	-	H1	x	x				x	x	x	x	x		x	H	VH	8	VERY HIGH
Coho Salmon	*Oncorhynchus kisutch*	Yellow	E[f]	H1	x	x	x			x	x	x	x	x		x	H	VH	8	
Bull Trout	*Salvelinus confluentus*	Blue	-	H1	x		x			x	x	x	x	x	x	x	H	VH	8	
Dolly Varden	*Salvelinus malma*	Blue	-	H1	x	x	x			x	x	x	x	x	x	x	H	VH	8	
Chiselmouth	*Acrocheilus alutaceus*	Blue	NaR	H1,D[g]					x	x		x					L	M	8	
Brassy Minnow	*Hybognathus hankinsoni*	Yellow	-	L1, D[h]	x	x				x							L	M	8	
Pygmy Whitefish	*Prosopium coulteri*	Yellow	-	H3, D[i]			x		x	x	x	x	x				M	H	8	

[a] Difficult to determine – likely, between 10-20% of global population occurs in British Columbia.
[b] Nechako, Upper Fraser, Lower Fraser, Kootenay and Columbia populations.
[c] Nechako, Upper Fraser, Middle Fraser, Lower Fraser, Kootenay and Columbia populations.
[d] Interior Fraser River population.
[e] Low stewardship responsibility for species (yellow-listed), 100% stewardship responsibility for Williston Watershed population (Red-listed).
[f] 100% of global range of listed populations of the Quesnel, Lakes and Prince George TSAs occur in British Columbia.
[g] Populations in British Columbia may be disjunct, relictual populations, especially the population found in the study area.
[h] Populations in British Columbia and Alberta are disjunct from the main population in central North America.
[i] Population in British Columbia is part of a relict, disjunct population.

[1] Attributes are summarized in Table 3.

Table 3. Summary of conservation status, stewardship responsibility and life history traits affecting sensitivity to logging used to rank fish species into categories of conservation concern (Table 2).

BC Status: Provincial conservation status designated by the Conservation Data Centre (CDC). Red: endangered; Blue: threatened or special concern; Yellow: not at risk.
COSEWIC: Conservation status designated by the Committee on the Status of Wildlife in Canada (COSEWIC). E: endangered; NaR: not at risk; -: not listed.
Stewardship: Level of stewardship responsibility according to extent of global range in BC.
H1: moderate – 30-50% global range or population in BC; H2: High – 50-75% global range or population in BC; H3: Very High - >75% global range or population in BC.
L1: Low, peripheral category 1 - <10% of global range or population occurs over less than 30% of BC; L2: Low, peripheral category 2 - <10% global range or population occurs over >30% of BC (adapted from Bunnell et al. 2004a,b).
Spawning habitat: Spawn in *small creeks and headwaters* - the most altered aquatic habitat type after logging.
Juvenile habitat: Juveniles reared in *small creeks and headwaters* - the most altered aquatic habitat type after logging.
Fall spawning: Spawns in fall and eggs may be destroyed by *increased flow* in fall that is constrained to the immediate watercourse by stream-side snowpack.
Benthic: primarily benthic in rocky *areas* and may be killed by *increased flow* due to logging.
Gravel: Broadcast spawning; require silt-free gravel areas for spawning, which may be unavailable due to *post-logging siltation*.
Feeding: Visual feeding; not adapted to low light levels, or feeds on algae; thus, foraging ability may be inhibited by *post-logging siltation*.
Oxygen: Intolerant of low oxygen, or found mostly in oligotrophic systems; therefore susceptible to *post-logging siltation* or any decreases in flow speed resulting from forest practices.
Turbidity: Intolerant of turbidity or usually found in clear water - high levels of turbidity result in physiological stress or mortality; therefore susceptible to *post-logging siltation*.
Temperature: Low tolerance for high temperatures that may result from removal of riparian vegetation or found mostly in cold water.
CWD: requires coarse woody debris (CWD) for cover from predators. In-stream CWD declines over time when riparian areas are harvested.
k-selected: Long generation times, delayed sexual maturity, resulting in slow recovery of populations that have declined due to disturbances, such as forest practices.
Movements: Extensive movements which may be inhibited by logging road culverts or debris jams.
Sensitivity General: Ranking of relative sensitivity to forest practices based on life history traits. L: low – sensitive in 1 – 3 life history traits; M: moderate – sensitive in 4 – 6 life history traits; H: high – sensitive in 7 – 12 life history traits.
Sensitivity Salvage: Ranking of relative sensitivity to salvage logging based on life history traits related to use of small creeks and headwaters (shaded), increased flow rate and post-logging siltation. L: low – sensitive in 1 – 2 life history traits; M: moderate – sensitive in 3 – 4 life history traits; H: high – sensitive in 5 – 6 life history traits; VH: very high – sensitive in 7 – 8 life history traits. 'Temperature' and 'CWD' were included for species that spawn or rear in small streams.
Conservation Concern: Ranking of relative conservation concern. Species with disjunct populations given highest ranking (8), all other species were ranked using sensitivity to salvage logging (low, moderate, high) and level of stewardship responsibility (peripheral, moderate, high):

LOW - low, peripheral (L|L2): 1; low, moderate (L|H1): 2; moderate, peripheral (M|L2): 3;
MODERATE - high, peripheral (H|L2): 4; moderate, moderate (M|H1): 5;
HIGH - moderate, high (M|H2:6); high, moderate (H|H1): 7;
VERY HIGH – very high, moderate (VH|H1): 8.

Two species with populations for which BC has very high stewardship responsibility, the white sturgeon and arctic grayling, were given ranks of 4 and 6 respectively.

Barriers to movement
Forest practices can result in increased barriers to fish movements through inadequately designed road culverts, debris jams and sedimentation. The negative effects of such barriers are likely greatest for species that migrate long distances between overwintering and spawning areas. Barriers to movement caused by areas of low water flow may lessen with logging-related increases in water flow. However, because flows generally decrease to below pre-logging levels as the landscape regenerates, this may result in the isolation and subsequent extinction of populations that have moved.

Increased flow in fall, a natural occurrence in the Pacific Northwest, causes juvenile salmonids to move into side-channels, which provide shelter from fast-moving water, higher water temperatures, and abundant invertebrates. Thus, connections between mainstems and side-channels must be maintained to ensure juvenile survival (Bramblett et al. 2002; Giannico and Hinch 2003).

Sedimentation
Sediment input to freshwater is due to either the slower, large-scale process of soil erosion, or to rapid, localized "mass movements," such as landslides. Forest practices can increase the rate at which both processes occur. Most sediment from forestry arises from landslides from roads and clearcuts on steep slopes, stream bank collapse after riparian harvesting, and soil erosion from logging roads and harvested areas. Roads, particularly those that are active for long periods of time, are likely the largest contributor of forestry-induced sediment (Furniss et al. 1991). Sediment can increase even when roads comprise just 3% of a basin (Cederholm et al. 1981). This observation lends additional support to the earlier recommendation:

- *Get in and out of salvage areas quickly, and deactivate new roads.*

More than half the species present in the study area will likely be negatively impacted by sedimentation from logging roads (Table 2). In areas made highly turbid (cloudy) from sedimentation, the foraging ability of adults and juveniles may be inhibited through decreased algal production and subsequent declines in insect abundance, or, for visual-feeding taxa dependent on good light, through their inability to find and capture food. Highly silted water may damage gill tissue and cause mortality or physiological stress of adults and juveniles. The majority of the freshwater fish (25 of 29) in the Lakes, Quesnel, and Prince George TSAs require silt-free, gravel areas on which to spawn. Sedimentation of gravel incubation sites can result in decreased oxygen availability to eggs and alevin (larvae with the yolk sac still attached) and may block the emergence of fry as the spaces between gravel pieces are filled. Unlike salmonids which bury their eggs in "redds," most of these species (18 of 25) simply broadcast their eggs and do not tend them, and are thus likely to be more susceptible to sedimentation. Mass movements like landslides also can cut off access to side channels, which are needed by some species as spawning habitat or as refuge from high water flows (Bramblett 2002).

Removal of riparian vegetation
Removal of riparian vegetation has four major negative effects on fish habitat: increased sedimentation from stream bank collapse, changes in water temperature, changes in primary productivity, and, over the longer term, a decline in the abundance of coarse woody debris . The effects of riparian removal are largest in relatively small, narrow, and shallow water bodies, such as headwater streams, which are used for spawning by many species, especially salmonids.

Temperature and primary productivity
Removal of riparian vegetation in small streams can increase average water temperature by as much as 10 °C, and maximum temperatures by as much as 16 °C. These temperature changes can persist over long periods, up to 10-15 years (Johnson and Jones 2000). Changes in water temperature are especially harmful to cold-water adapted fish that spawn and rear in small streams, such the bull, rainbow, and cutthroat trout, the coho salmon, arctic grayling, and the

Dolly Varden. Increases in stream temperature can cause growth inhibition, reduced survival, increased disease and alteration of egg and juvenile development (Beschta et al. 1987).

Increased fish production has been observed shortly after riparian logging due to increased light and temperature resulting in increased primary productivity, and thus food availability (Murphy and Hall 1981; Hetrick et al. 1998; Fuchs et al. 2003). However, increased productivity in the first 20 years after harvest is usually followed by production below pre-harvest levels because dense regenerating riparian vegetation does not admit as much light as old growth. Over the long term, decreased in-stream productivity results in decreased abundance of an invertebrate food source.

Coarse woody debris
Removal of riparian vegetation results in less input of coarse woody debris into waterbodies over the long-term. Riparian areas that regenerate with deciduous trees provide less coarse woody debris because deciduous wood decays faster than conifer wood and is generally smaller. Rotations of less than 100 years result in permanent depletion of the large coarse woody debris necessary to maintain stream conditions. Coarse woody debris provides habitat by creating large, deep pools of slow-moving water, which the adults and older juveniles of some species, salmonids in particular, require both energetically and as cover from predators. Coarse woody debris also creates riffle areas, important habitat for younger juveniles, and spawning habitat because it traps gravel and breaks up steep areas into areas of deep pools and riffles, giving the stream areas of lower gradient (Spangler and Scarnecchia 2001).

The combined effects of removal of riparian vegetation lend further support to the earlier recommendation:

- *Follow former Forest Practice Code guidelines when harvesting near streams and rivers.*

The potential exaggerated effects in small streams leads to the further recommendation:

- *Avoid any mechanical or other disturbances in or within 20 m of S3 and S4 streams.*

Species found throughout the study area that are likely to be severely impacted by logging to the bank of small streams are the bull trout and rainbow trout. Other species are likely to be similarly impacted but have more localized distributions (Table 2 and maps in “Species accounts”).

Eventually, buffered streams through lodgepole pine stands will likely experience debris torrents; this is addressed under “Effectiveness and implementation monitoring.”

Hydrology
Clearcut logging results in greater runoff and higher water volume in water bodies. Generally, increased water yield only occurs when more than 20-30% of a watershed has been cleared (Bosch and Hewlett 1982). Above this level, the more vegetation removed and the more soil is compacted, the greater the runoff. Logging generally results in higher peak flows in coastal areas in the fall and spring, when rainfall is greatest. In the interior (snow-dominated hydrology), logging results in higher peak flows in the spring when snow is melting (Chamberlin et al. 1991). High water volumes can wash away incubating eggs and may result in the mortality of juveniles and adults, particularly of taxa that are bottom-dwelling in rocky areas.

Most salmonid species bury their eggs in “redds,” nests excavated in the clean gravel of stream beds. Eggs and alevin (larvae with the yolk sac still attached) are vulnerable to stream bed disturbances during this time. Scouring of the gravel bed by high water flows can result in egg and alevin mortality as high as 80-90%, and causes greater mortality at this stage than suffocation from sedimentation (Tripp and Poulin 1986). The mortality rate from scour increases whenhigh flow rates happen during incubation. Winter-incubating salmonids like the coho, pink, chinook, bull trout and Dolly Varden are most vulnerable on the coast, where peak flows due to high rainfall occur in the fall and winter. Spring-incubating species like the rainbow and cutthroat trout are most vulnerable in the interior where hydrological regimes are dictated by spring snow-melt.

Mitigation of potential increases in sedimentation or changes to the hydrological regime will be aided by following practices of the former Forest Practices Code (e.g., by avoiding unstable terrain). The recommendation made earlier to *retain species other than lodgepole pine during logging* also will aid mitigation and benefit freshwater fish species.

The area of the three TSAs includes the range of pygmy whitefish that is both uncommonly sensitive to salvage logging and for which the TSAs have high stewardship responsibility. The range of this species (see "Fish species accounts") is an obvious candidate for large unsalvaged areas, congruent with the recommendation:

- *Avoid salvage in selected areas where intermixed pine represents <40% of the species mix.*

We recommend that

- *Leave areas should include areas in which there are high densities of fish species that are highly sensitive to salvage logging, and for which the province has high stewardship responsibility.*

As well as the pygmy whitefish, these species include the mountain whitefish, rainbow trout, cutthroat trout, coho salmon, bull trout, and Dolly Varden (see maps under "Fish species accounts").

Fish species accounts

Habitat information was summarized from Roberge et al. 2002 and supplemented by sources cited for individual species. Range maps were produced using data in the Fish Information Summary System available online at [http://srmapps.gov.bc.ca/apps/fidq/fissSpeciesSelect.do]. The species accounts file is large because it contains maps. To facilitate electronic transfer, this file can be found online at http://142.103.128.161/uploadedFiles/fish-species%20accounts.pdf

Non-Forest-dwelling terrestrial vertebrates

There is no tidy boundary between forest-dwelling vertebrates and other vertebrates. Many of the species we consider non-forest-dwelling, such as the spotted frog, American bittern or woodchuck, use small inclusions of specialized habitats within forests. These species can be affected by practices in the adjacent forest. We consider there to be 112 species of vertebrates within the three TSAs that are not wholly forest-dwelling. This total includes 102 bird species, 9 mammals, and 1 amphibian. Among these, the short-eared owl is considered to be of "special concern" by COSEWIC. It also is blue-listed (i.e., considered vulnerable) by the BC CDC, along with five other species of birds. The American white pelican is red-listed (i.e., threatened or endangered). Five of the species that are red- and blue-listed in British Columbia occur on the list of "Identified Wildlife Species-2004" – American bittern, American white pelican, sandhill crane, trumpeter swan and long-billed curlew. Short-eared owl and California gull are blue-listed but are not on the "identified wildlife Species" list.

Although about a third (38) of the non-forest-dwelling birds do not breed in the study area, they rest and forage in it during migration or at other times. Birds require abundant and reliable sources of food during migration when they expend much energy and lose significant amounts of body weight (Welty and Baptista 1988). Migration habitats are as important as nesting habitats and should receive equal management consideration. These 38 species rest and forage mostly in wetlands and/or grasslands (Appendix III).

Impacts of logging on non-forest-dwelling species

Wetland, lake and river species
The majority of non-forest-dwelling species of terrestrial vertebrates (63%) that occur in the three TSAs depend on wetlands, rivers and riparian habitat. Forty-two (38%) of these species breed in the area and build their nests in emergent vegetation, or in riparian areas and on islands. Twenty-seven (24%) of these species forage in aquatic habitat during migration through the area.

Removal of riparian forest may provide short-term increases in primary production and food availability for some aquatic birds (see "Impacts of logging on fish"). However, in the longer term, riparian removal may be detrimental because it degrades nesting habitat. Riparian buffers also are critical for some species of aquatic birds because they protect them from disturbance. Human activity and disturbance near nesting wetlands may cause some species, such as the blue-listed sandhill crane, to abandon their nests. Logging that results in sedimentation and turbidity may negatively impact the ability of aquatic-foraging birds to visually hunt prey (see "Impacts of logging on fish").

Logging and roads result in greater runoff and higher water volume in water bodies (see "Impacts of logging on fish"), and may result in flooding of nests and foraging and roosting habitat in riparian areas. Large-scale salvage logging is likely to affect wetland, lake and river habitat through more roads, more activity and disturbance, and more open soil that is more susceptible to erosion. These observations support the widespread need of some recommendations offered above for forest-dwelling species. Specifically,

- *Follow former Forest Practice Code guidelines when harvesting near streams and rivers*
- *Get in and out of salvage areas quickly, and deactivate new roads wherever possible.*
- *Avoid salvage in selected areas where intermixed pine represents <40% of the species mix.*

The latter recommendation will help to minimize the construction of new roads. As well, we recommend:

- *Retain unharvested riparian buffers around wetlands and lakes.*

Large-scale salvage logging will increase the cut over a short period of time, possibly increasing the need for log storage areas. The formerly common practice of storing logs in lakes should be avoided. When such storage areas are used they usually are located in shallow and sheltered waters. It is these very areas that often offer the highest quality foraging and nesting habitat, with abundant aquatic vegetation and food sources. That practice should be avoided.

- *Avoid log storage within lakes.*

Grassland species
Twelve species in the area depend on grassland for breeding or foraging during migration. Sometimes these can occur as small inclusions within forests. Generally, there are no apparent threats from forest practices to grassland habitat, unless access roads cross the nesting grounds. The main threat to grasslands is urban and agricultural encroachment. Habitat is altered because of overgrazing by livestock, fire suppression, introduction of alien species in the dry grassland, and pesticide application (Cannings et al.1999; Fraser et al. 1999).

Other habitat type users
Nine non-forest-dwelling vertebrate species occur in alpine areas. Seventeen species use a number of non-forested habitats (e.g., agriculture fields, urban, all types of open habitats) and are not restricted to one in particular . Other species have more specific habitat requirements such as rock outcrops and cliffs. These species are unlikely to be affected by forest practices.

Listed species – non-forest-dwelling terrestrial vertebrates

Of the 112 species of vertebrates that are not forest-dwelling and occur in the area of the three TSAs, seven are designated "at risk" by the BC CDC. The first five listed use wetlands; the last two use grasslands.

American bittern: Blue-listed by the CDC; Identified Wildlife 2004.
American bittern relies on wetlands for its breeding habitat. The species is susceptible to removal of riparian vegetation, disturbance of wetlands, and to changes in water regimes. Nests are built among tall vegetation emerging from water up to 35 cm deep, and nesting sites tend to be in areas where water levels are stable (Cooper and Beauchesne 2003; Campbell et al. 1990*a*). It forages primarily in marshes, but also in sloughs, lake edges, swamps, riverbanks and sewage ponds. Breeding occurs in lowland marshes in lakes, ponds and rivers.

American white pelican: Red-listed by the CDC; Identified Wildlife 2004.
In British Columbia, American white pelican only breeds at Stum Lake, outside the salvage logging area, but forages up to 165 km away over an area of 30 000 km^2, which includes the Quesnel TSA (Campbell et al. 1990; Harper and Vanspal 2004). The species forages in shallow water along shorelines, streams, at creek outlets and in shallow open water (Campbell et al. 1990a; Harper and Vanspal 2004). Possible threats from salvage logging are disturbance of foraging birds or increased water levels that flood high-quality foraging and roosting habitat.

California gull: Blue-listed by the CDC.
In the salvage logging area, California gull breeds on Gravel Island in the Quesnel River (Fraser et al. 1999). Foraging occurs in open areas such as agricultural fields, meadows, beaches, and in lakes and rivers (Campbell et al. 1990*b*). The species is susceptible to human disturbance. However, there are no apparent threats from salvage logging provided that the nesting area (Gravel Island) is not disturbed.

Sandhill crane: Blue-listed by the CDC; Identified Wildlife 2004.
The Sandhill crane breeds in low-elevation (<1200 m) bogs, marshes, swamps and meadows with emergent vegetation. Possible threats from logging are disturbance of foraging birds, removal of riparian vegetation, or increased water levels that flood high-quality foraging and roosting habitat. This species is very sensitive to human disturbance. Nesting areas are usually isolated and adjacent to riparian forest that provides buffer against disturbance and escape cover for the young (Campbell et al. 1990*b*; Cooper 1996; Fraser et al. 1999). Logging activities, aircraft overflight, and noise can cause nest abandonment.

Trumpeter swan: Blue-listed by the CDC; Identified Wildlife 2004.
The trumpeter swan is a wetland species that breeds throughout boreal British Columbia, primarily in the Peace Lowlands, and winters mostly on the coast of British Columbia (McKelvey 1981 reviewed in Campbell et al. 1990*a*). There are no breeding records in the area of the three TSAs (Campbell et al. 1990a). There are no apparent threats from salvage logging in the study area provided that foraging areas are not disturbed or flooded. The species is sensitive to disturbance.

Long-billed curlew: "vulnerable" by COSEWIC; Blue listed by the CDC; Identified Wildlife 2004.

Long-billed Curlew breeds in the southern portion of the Quesnel TSA (Cannings et al.1999). The species builds nests on the ground of open, dry grasslands with short vegetation (< 25 cm tall) below 1200 m elevation (BCMELP 1998; Fraser et al. 1999). There is little threat from forest practices, though logging roads through grasslands may disturb nesting birds. The main threats are the loss of grasslands due to urban and agricultural encroachment.

Short-eared owl: "Special Concern" by COSEWIC; Blue-listed by CDC.
Short-eared owl occurs in the study area, but there are no breeding records (Campbell et al. 1990). It is associated year round with open spaces such as grasslands, brushy fields, marshlands, alpine meadows and clearcuts (Campbell et al. 1990*b*). Open habitats facilitate hunting of small mammals. Members of this species fluctuate with prey populations and select breeding grounds in areas of high rodent densities (Ehrlich et al. 1988). There is little threat from logging, but silvicultural activities such as burning and spraying may impact the habitat and availability of prey.

Other values

This report treats the potential impacts of large-scale salvage logging on vertebrates. Such logging clearly affects other values as well. Effects on other components of biodiversity (e.g., bryophytes, lichens) have been noted briefly. It is important to recognize that the recommendations made here also affect economic and social values. For example, the retention of trees other than lodgepole pine ensures that there is some harvest in the relatively near future after salvage logging is completed. That provides some continuity of economic return after the pine has been removed and returned to a much younger, non-commercial age class. That in turn provides social benefits and returns to the local communities. Following the recommendations to sustain biological diversity also works to help sustain desirable social and economic outcomes.

Effectiveness and implementation monitoring

British Columbia has never experienced a salvage operation on the scale proposed for the Lakes, Prince George and Quesnel TSAs. Though recovering wood and value from wood will be a dominating priority, other values will be considered during salvage practices. Given the unprecedented nature of salvage operations, the effectiveness of management practices in sustaining biodiversity should be monitored.

The best effectiveness monitoring program for forest-dwelling biodiversity in the province is that of Weyerhaeuser on the coast (Bunnell et al. 2003; Kremsater et al. 2003). Other forest companies have adopted the three broad indicators proposed for Weyerhaeuser (e.g., Canadian Forest Products and Tembec) as has the Biodiversity Branch of the Ministry of Water, Land and Air Protection. Any effectiveness monitoring program should be designed to address specific objectives. Although the objectives of the Weyerhaeuser approach and the objectives for salvage operations are clearly different, the broad indicators used to assess responses of biodiversity can be the same. The generic indicators developed for Weyerhaeuser have the additional advantage that when monitoring is suitably designed, they are capable of linking back to management and providing guidance to management actions (Bunnell and Dunsworth 2004). That is, the approach works. Acknowledging the utility of the approach and its current use, we propose the following criterion and indicators for monitoring the effectiveness of management practices during salvage logging in sustaining vertebrate species richness:

Criterion: Native species richness[3] is sustained within the Lakes, Quesnel and Prince George TSAs.

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[3] Although recommendations have been made specifically from consideration of better known vertebrates, they will serve to sustain other organisms as well, including bryophytes, lichens, fungi, vascular plants and non-pest invertebrates (references in text).

Indicator 1: Amounts and area of tree species other than lodgepole pine harvested during large-scale salvage operations do not increase beyond that expected from normal operations.

Indicator 2: The amount, distribution and heterogeneity of stand and forest structures required to sustain native species richness are maintained over time.

Indicator 3: The abundance, distribution and reproductive success of native species are not substantially reduced by salvage operations.

The criterion represents the measure of success; the indicators represent ways of assessing whether success is attained. As described below, measures for these indicators encompass both planning and practices. Planning must consider areas that are not salvage logged as well as areas that are logged.

Because salvage logging must occur rapidly for it to be effective, there may be too little time to develop a complete effectiveness monitoring program. In some instances below, the indicators are cast more as implementation monitoring. Implementation monitoring usually assumes *arbitrary* initial targets that must subsequently be evaluated for effectiveness. Given that the outbreak shows no sign of abating, the goal should be to supersede implementation monitoring with effectiveness monitoring as rapidly as possible.

There invariably are more questions than resources to answer questions in any program of effectiveness monitoring (Bunnell and Dunsworth 2004; Houde et al. 2004). It is thus important to winnow down the number of questions and focus monitoring on those that appear to have the greatest ecological or economic uncertainty and potential impact. Based on the preceding review, we have attempted to do that for each indicator.

Indicator 1

During large-scale salvage operations, amounts and area of tree species other than lodgepole pine harvested during large-scale salvage operations do not increase beyond that expected from normal operations.

Indicator 1 represents a coarse filter usually focused on distinct ecosystem types and intended to sustain lesser known species and functions. For salvage logging it is focused on tree species other than lodgepole pine and on riparian areas. Defining and implementing the coarse filter well is the most cost-effective approach to monitoring. Retaining trees other than lodgepole pine and riparian forest will do more to sustain native species richness within the study area than any other single practice (see “Forest-dwelling vertebrates” and “Freshwater Fish” above). Moreover, reserving these species and areas from harvest contributes significantly to other values, including social and economic values (see “Other values” above).

Monitoring questions

The most revealing or helpful questions include:

1) Are tree species other than lodgepole pine being removed at rates higher than had been planned or anticipated prior to salvage logging?
2) Are riparian areas being maintained during salvage?
3) Where can the greatest gains be accrued from leaving extensive tracts of dead lodgepole pine?

Methodologies

Considerations and methodologies for addressing each question are considered separately:

Are tree species other than lodgepole pine being removed at rates higher than had been planned or anticipated prior to salvage logging?

Because this is the coarse filter, measures available across the study area must be employed. In some areas a relatively detailed representation analysis has been completed (e.g., Vanderhoof Forest District, FESL 2004; TFL 30, FESL 2003). These analyses permit identification of riparian, uncommon and rare ecosystem types. Where such analyses exist, the most uncommon ecosystem types should simply be excluded from salvage. Even if all trees were to die, it is probable that the soil flora and fauna will be relatively unaffected. For many areas, representation analysis will not be available. In those cases, the most applicable widespread measure is forest cover. The goal is to retain species other than lodgepole pine to the extent possible. That can be implemented at the planning stage, simply by focusing effort on pine-leading types, then evaluating the degree to which species other than lodgepole pine are being retained as retention patches. Convenience and pursuit of cost-effectiveness will encourage removal of small inclusions of non-lodgepole pine species, including upland hardwoods in some instances, some of which may not appear on forest cover maps. One simple approach is to monitor truckloads of non-lodgepole species, and view any that exceed planned removal as reducing effectiveness.

Another simple alternative is to accept arbitrary initial targets for implementation monitoring. For example, at least 80% of non-pine live trees should remain behind after salvage on 50% of the block area, 60% on 30% of the block area, and 40% on 20% of the block area. The block area would be summed across all blocks within a landscape –unit or watershed. That would accommodate the variable operational flexibility, but cannot be considered effectiveness monitoring.

Are riparian areas being maintained during salvage?
Monitoring the degree to which riparian areas are reserved from harvest is straightforward in most instances. It can be recorded simply as the buffered proportion of the length of streams within cutblocks. Exceptions are small streams, which may not be well mapped, and wetlands, which may not be recognized as riparian sites. The wetland sites are particularly important to a number of species that are largely restricted to them (see "Non-forest-dwelling vertebrates"). The obvious approach is to treat the margins of wetland areas like any other riparian area and leave an unharvested buffer around them. Buffers of 20 to 30 m should be sufficient for most wetland species. Note that even small wetland inclusions are significant for some vertebrates (Appendix II). Thus, it is more important to assess what proportion of the *number* of wetland areas is buffered, than the proportion of the *total area* of wetlands buffered.

While the precautionary principle would argue that all small streams should be buffered, it is known that particular fish species in the area inhabit known S3 and S4 streams. Moreover, some of these fish species are sensitive to changes that could be induced by salvage logging ,e.g., changes in water temperature, sedimentation and turbidity (Table 2). Sensitive fish species are summarized in Table 2; their locations are shown on the maps for each fish species in Appendix II. Therefore, effort to maintain riparian buffers and effectiveness monitoring of buffers around small streams can be focused where such buffers will be most useful. The simplest measure again is the buffered proportion of length of streams within cutblocks.

Where can the greatest gains be accrued from leaving extensive tracts of dead lodgepole pine?
This question addresses the issue of how to target salvage areas – some areas should be avoided during salvage and other areas selected. There are several reasons for leaving large expanses of pine unharvested, not the least of which are economics and avoiding a proliferation of roads. There are 11 species in the area that are considered forest "interior" species, but it is unlikely that any of these species will find extensive tracts of dead pine favourable habitat. However, for the black-backed and three-toed woodpeckers such tracts are preferred habitat. From the perspective of organisms there are three major considerations: caribou (for which guidelines exist), poorly known non-vertebrate species, and localized fish populations sensitive to temperature, sedimentation, or turbidity. The woodpeckers may be mobile enough that amount rather than location is most important. Where representation analyses exist and uncommon

ecosystem types are known and mapped, the degree to which these are included in unharvested areas is a measure of effectiveness. Most of the poorly known flora and fauna dwell in the soil and may be relatively little affected by the death of the overstory. Similarly, the inclusion of ranges of sensitive fish species into larger unharvested tracts also is a measure of effectiveness.

Salvage logging should be focused on areas where rapid regeneration and subsequent growth is likely. A potential problem is that the beetle kill plus salvage operations will leave large areas not sufficiently restocked, but rapid regeneration is needed so that future requirements for both wood and habitat are attained as rapidly as possible. Similarly, salvage could be focused on higher quality sites or other sites where subsequent management can encourage faster generation of stand attributes needed to sustain biological diversity.

Research questions

Does the increased rate of cut produce undesirable effects on hydrology, water temperature and turbidity or sedimentation?

Given that the rates of cut will be greater than previously experienced, the consequences may be undesirable. Any research around this question should specify measures of "undesirable."

Do streams flowing through lodgepole pine acquire undesirable characteristics once the lodgepole pine have died?

Avoiding harvesting of riparian areas to help maintain other values may eventually lead to undesirable in-stream effects. Although the current magnitude of bark beetle infestation is novel, fires have historically generated similar impacts on streams. Research on this topic might best begin with review of documented fire effects. Again, any research around this question should specify measures of "undesirable."

What are the temporal trajectories of habitat elements in stands not salvage logged?

Without this knowledge it is difficult to plan location of salvage so that large contiguous areas are not devoid of particular elements. The knowledge also could guide harvest methods, including stubbing to create cavity sites, and appropriate amounts or sizes of dead wood left on the ground.

Can we target large salvage areas to minimize future impacts on wood supply and habitat?

Any retained stands will be sought quickly if the salvaged areas are not rapidly regenerated. The best guarantee of future habitat is thus rapid regeneration. Considerations include: 1) known regeneration opportunities (e.g., spruce understory); 2) high quality land that may regenerate quickly, grow quickly or otherwise provide opportunities for stand management to quickly create stand structures needed to sustain biological diversity; and 3) possible salvage on riparian areas if they can be restocked quickly. Note that in terms of planning, it might be effective to build longer roads and target the back of valleys. Road access would then permit planting on intervening unsalvaged areas. That action is contrary to the recommendation to deactivate roads, and is not acceptable everywhere.

Indicator 2

The amount, distribution and heterogeneity of stand and forest structures important to sustain native species richness are maintained over time.

During effectiveness monitoring of forest practices, Indicator 2 serves as a medium filter intended to assess whether the amount and kind of habitat left after harvesting is effective in sustaining wildlife species. It typically focuses on the habitat elements and structures that are known to be important in sustaining forest-dwelling organisms. That is, it relies on existing knowledge to determine what elements or structures are likely to be most important. In terms of salvage logging, the recommendations made above are derived from that same knowledge and specify the elements that should be retained during harvest. Until studies of the organisms themselves prove otherwise, Indicator 2 can likely best be monitored by assessing the degree to which those specified elements are retained. Such monitoring is thus more aptly described as implementation monitoring, but serves to describe the effects salvage logging is having on elements of forest habitat believed to be most important. An equally important component of stand structure is the state of regeneration. Regeneration is important not only to the continued provision of habitat but also to economic and social values. To better guide future planning, the trajectories of stand attributes in stands not harvested also should be known (see “Research questions” for Indicator 1).

Monitoring questions
Because of the slow rate of change in forests, not all relevant questions can be addressed within the same time period. These questions, however, include:

1) Are unharvested areas of lodgepole pine being regenerated?

2) What is the nature of retained patches within salvage cut blocks?

3) Are major habitat elements being retained?

Methodologies
Considerations and methodologies for addressing each question are considered separately:

Are unharvested areas of lodgepole pine being regenerated?
Recommendations to sustain other values include leaving extensive areas of lodgepole pine and avoiding riparian areas. It is not known if areas reserved from salvage logging will be satisfactorily regenerated naturally. The developing condition of dead stands may preclude planting. It is thus critical to assess quickly the potential delays in the provision of habitat and economic values within unsalvaged stands. Upland and riparian stands may respond differently and surveys of regeneration must be stratified, but methodologies are well established.

What is the nature of retained patches within salvage cut blocks?
The retained patches are a form of variable retention and methods of evaluating Indicator 2 within variable retention blocks are well described in Bunnell et al. 2003. Given the extensive area of salvage logging, however, those methods may have to be simplified. The most critical measures include: number of patches, size of patches, and species composition of patches. These data should be recorded on a cutblock basis to assess area of retention attained. Where riparian buffers are included as part of retention, these should be recorded separately.

Are major habitat elements being retained?
A full accounting of the degree to which habitat elements are being attained would include the larger unsalvaged areas as well as retained patches. Again, Bunnell et al. (2003) provide a monitoring approach appropriate to variable retention. Provided that hardwoods are being adequately sampled under the preceding question, in areas under bark beetle attack the key habitat elements appear to be cavity sites, shrubs and downed wood. Hardwoods readily provide cavity sites, but some organisms seek conifers. Effectiveness monitoring should track the amount and species of retained conifer stems over 30 cm in diameter. Lodgepole pine stubs over 30 cm created during salvage also should be tracked. There are two issues with shrubs: the first is that recommendations include avoiding vegetation management in salvaged areas, and shrubs could proliferate to the point of impeding regeneration; second, shrubs may respond well underneath dead lodgepole canopies in unsalvaged areas, thus potentially reducing the need to avoid vegetation management in salvaged areas. The latter observation emphasizes that habitat elements should be monitored in both salvaged and unsalvaged areas. The issue with downed wood or coarse woody debris is primarily that of excessive amounts in unsalvaged stands. These amounts could simultaneously inhibit regeneration, increase fire hazard, and reduce ungulate access. Provided non-lodgepole species are retained, and not all debris is yarded in, there should not be a lack of downed wood on salvaged sites.

Research questions
What is the most effective way of using fire to encourage regeneration in harvested stands?
A portion of this question was asked under Indicator 1 that tends to guide operational planning. Lodgepole pine is a fire-adapted species. Given that recommendations for biodiversity and social values include retaining non-pine species and encouraging shrubs, it is unclear how fire can be used to encourage pine regeneration. Use is expected to be different in areas salvage logged and those left unlogged.

Does prescribed fire have a role in abatement of hazard in unsalvaged stands?
The eventual breakup of pine within unsalvaged stands suggests that fire hazard could be high. It will be helpful to learn whether prescribed fire can reduce the hazard and encourage regeneration.

Can sites where vegetation management is required be clearly defined?
Recommendations to sustain biodiversity include avoiding vegetation management. There may be sites where that recommendation reduces economic return. It will be helpful to know the relative area of these sites and to consider the issue in terms of shrub growth within unsalvaged stands.

What are the fall rates of dead trees?
A broader question of habitat trajectories was noted under Indicator 1, with regard to coarse filter planning. Cavity sites are of particular interest. Currently, we do not know how long beetle-killed pine will stand and provide cavity sites or other habitat features. Extrapolation of data from elsewhere suggests at least 10 to 15 years (references above), but it would help planning to quantify local values for the large areas of beetle kill.

What are the consequences of debris levels in unharvested areas?
There will be a gradual accumulation of debris as unharvested stands break up. This debris could inhibit regeneration and wildlife use, and increase fire hazard. Presently, the magnitude of these likely consequences is unknown.

Indicator 3
The abundance, distribution and reproductive success of native species are not substantially reduced by salvage operations.

Organisms themselves are the finest filter in monitoring. Their sustained presence is the ultimate test of the effectiveness in sustaining biodiversity. There are far too many species to monitor individually. Any individual species must be selected carefully, and should meet four criteria: 1) be forest-dwelling, 2) be sensitive to the forest practices employed, 3) be practical to monitor, and 4) provide information useful in guiding forest practice. Commonly, vascular plants or songbirds are used in monitoring because many have known links to forest practices so their responses can be interpreted. Not all of these species will be sensitive to the impacts of salvage logging, and some are likely to respond positively. Further, birds may be the least impacted because of their ability to move large distances. Neo-tropical migrants are unlikely to provide much information because small changes in presence or reproduction may be more related to conditions on wintering grounds. Provided that the general recommendations are followed, the primary impact of salvage logging should appear among those species that are believed to require forest interior, including caribou. Some of these species, e.g., fisher, are impractical to monitor.

Monitoring questions
Experience elsewhere suggests that monitoring immediately after introduction of new practices can be misleading, because some initial responses are quickly muted and can change direction.

Because of the slow rate of change in forests, not all relevant questions can be addressed within the same time period. The questions, however, include:

1) Are those songbirds believed to be dependent on forest interior still present?

2) Do caribou continue to use lodgepole pine winter ranges after the pine are dead?

Methodologies
Considerations and methodologies for addressing each question are considered separately:

Are songbirds believed to be dependent on forest-interior still present?
Of the forest interior species present in the area, only the caribou and the songbirds are practical to monitor. At least four of the "interior" songbirds have songs or calls that can be heard at some distance: hermit thrush, varied thrush, white-breasted nuthatch, and black-headed grosbeak. These species are expected to be either absent or present only spottily in areas that are salvage logged. The major issue is whether they remain in areas that are unharvested. That is most unlikely where lodgepole pine comprises a large portion of forest cover. Where access is possible into unharvested areas, "listening posts" 400 m apart along roads would provide an index.

Do caribou continue to use lodgepole pine winter ranges after the pine are dead?
Monitoring should be focused on known lodgepole pine winter ranges. The simplest surveys are likely winter track counts, and in many instances should be relatable to previous surveys.

Research questions
What species are retained in large unharvested areas of lodgepole pine?
It is expected that species using small discrete habitats (e.g., ponds) will be unaffected. We know of no lichens or bryophytes limited to lodgepole pine, though the lichens *Kaernefeltia merrillii* and *Vulpicida canadensis* are many times more common on lodgepole pine than on any other tree species (T. Goward, Enlichened Consulting Ltd., Clearwater, BC. pers. comm.). The richness of vascular plants may increase after salvage. Songbirds are thus an appropriate group to monitor, but interpretation should be cautious in light of the above comments.

Which species continue to use retained patches (live and dead) in harvested areas?
As for large unharvested areas, the most appropriate group to monitor again appears to be songbirds. Methodologies for evaluating songbirds in patch retention have been developed by several researchers, with some of the most intensive studies occurring within Weyerhaeuser's Coastal Forest Strategy.

Which species use lodgepole pine stubs created during salvage, and which characteristics of stubs are sought?
The contributions pine stubs make to cavity-nesting birds also has been evaluated by several researchers in other areas (Harris 2001 is a recent study). The species mix in the areas under bark beetle attack will be different and findings may differ from other areas. It is thus important to document diameter and height of the stubs, and distinguish between feeding and nesting activity. The recommendation of a 30 cm minimum diameter is consistent with studies elsewhere, but may be excessive in more northern forests.

Are cavity users being lost from the study area?
As areas are salvage logged and as areas that are not salvaged logged break up, the most limiting habitat element likely will be cavity sites. Some cavity-using species should be little affected – cavity-nesting waterfowl should be retained in riparian areas, and the black-backed and three-toed woodpeckers appear to concentrate wherever the next beetle attack occurs. There remains an entire suite of cavity users that likely will be impacted, but the magnitude of impact is unknown.

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Appendix I. Forest-dwelling vertebrates and their habitat associations within the study area.

Common Name[1]	COSEWIC[2]	BC[3]	Neo[4]	Shr[5]	G[6]	E[6]	M[6]	L[6]	Cavity[7]	DW[8]	Dec.[9]	Con.[9]	R[10]	Edg.[11]	Int.[12]
AMPHIBIANS															
Order Caudata															
Long-toed Salamander					Y								Y		
Order Anura															
Pacific Treefrog					Y								A	Y	
Western Toad	SC				Y									Y	
Wood Frog					Y								Y		
REPTILES															
Order Squamata															
Common Garter Snake					Y								A	Y	
BIRDS															
Order Ciconiiformes															
Great Blue Heron		B			Y						Y		Y		
Order Anseriformes															
Barrow's Goldeneye					Y				Sec		Y		Y		
Bufflehead					Y				Sec		Y		Y		
Harlequin Duck				Shr	Y				Sec				Y		
Common Goldeneye					Y				Sec				Y		
Common Merganser					Y				Sec				Y		
Hooded Merganser					Y				Sec				Y		
Order Falconiformes															
American Kestrel			(R)		Y				Sec					Y	
Bald Eagle			(R)					Y					Y		
Cooper's Hawk			(R)		Y						Y				
Golden Eagle			(R)					Y							
Merlin								Y							
Northern Goshawk	T		R		Y							Y			
Osprey					Y							Y	Y		
Peregrine Falcon	T	R	(R)		Y								Y		
Red-tailed Hawk					Y									R+	
Sharp-shinned Hawk								Y				Y			
Order Galliformes															
Blue Grouse			R			Y				O		Y		R+	
Ruffed Grouse			R		Y					O	Y		Y	R+	
Spruce Grouse			R		Y					O		Y		Y	
White-tailed Ptarmigan			R		Y										

Appendix I.

Common Name[1]	COSEWIC[2]	BC[3]	Neo[4]	Shr[5]	G[6]	E[6]	M[6]	L[6]	Cavity[7]	DW[8]	Dec.[9]	Con.[9]	R[10]	Edg.[11]	Int.[12]
Order Strigiformes															
Barred Owl			R				Y	Y	Sec						Y
Great Gray Owl			R					Y				Y		R+	
Great Horned Owl			R					Y				Y		R+	
Long-eared Owl			R		Y						Y		Y	R+	
Northern Hawk Owl			R					Y	Sec						
Northern Pygmy-Owl			R				Y	Y	Sec			Y	Y	Y	
Northern Saw-whet Owl			R				Y	Y	Sec			Y			
Order Caprimulgiformes															
Common Nighthawk			N		Y										
Order Apodiformes															
Anna's Hummingbird				M	Y						Y			R+	
Calliope Hummingbird			N	M	Y						Y		Y		
Rufous Hummingbird			N		Y								Y		
Vaux's Swift			N					Y	Sec			Y			
Order Piciformes															
Black-backed Woodpecker			R					Y	P			Y			
Downy Woodpecker			R					Y	wP		Y				
Hairy Woodpecker			R					Y	P			Y		Y	
Northern Flicker					Y				wP		Y			Y	
Pileated Woodpecker			R					Y	P					Y	
Red-breasted Sapsucker							Y	Y	P		Y		A		
Three-toed Woodpecker			R					Y	P					Y	
Yellow-bellied Sapsucker			N					Y	P				A		
Order Passeriformes															
Alder Flycatcher			N	H			Y				Y		A		
American Crow					Y									Y	
American Dipper			R		Y								Y		
American Redstart			N	Shr		Y	Y				Y		Y		
American Robin			(R)		Y						Y		Y	Y	
American Tree Sparrow						Y							A		
Bullock's Oriole			N		Y						Y		Y	Y	
Black-and-white Warbler			N				Y						Y		
Black-billed Magpie					Y						Y			R+	
Black-capped Chickadee			R		Y				wP		Y			R+	
Black-headed Grosbeak			N	M			Y				Y				Y
Blackpoll Warbler			N		Y							Y	A		
Bohemian Waxwing					Y							Y			
Boreal Chickadee			R					Y	wP			Y			
Brown Creeper			R					Y	Cv			Y			Y
Brown-headed Cowbird			N		Y									Y	
Cassin's Finch							Y					Y			
Cassin's Vireo			N	M			Y								

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Common Name[1]	COSEWIC[2]	BC[3]	Neo[4]	Shr[5]	G[6]	E[6]	M[6]	L[6]	Cavity[7]	DW[8]	Dec.[9]	Con.[9]	R[10]	Edg.[11]	Int.[12]
Cedar Waxwing			N		Y						Y		Y		
Chestnut-sided Warbler			N	H	Y						Y			Y	
Chipping Sparrow						Y							Y		
Clarck's Nutcracker			R					Y				Y			
Clay-colored Sparrow				M		Y							Y		
Common Raven			R					Y				Y			
Common Redpoll			R	M	Y							Y			
Common Yellowthroat			N	H		Y					Y		Y	Y	
Dark-eyed Junco				Shr	Y										
Dusky Flycatcher				H		Y					Y		A	Y	
Eastern Kingbird			N	M		Y							Y	Y	
Evening Grosbeak			R				Y	Y				Y			
Fox Sparrow				M	Y								Y		
Golden-crowned Kinglet			(R)					Y				Y	Y		Y
Golden-crowned Sparrow						Y								R+	
Gray Jay			R				Y	Y				Y			
Hammond's Flycatcher			N					Y				Y	Y	R+	
Hermit Thrush			N	Shr	Y							Y			Y
House Wren					Y				Sec					Y	
Lazuli Bunting				H		Y									
Least Flycatcher			N			Y									
Lincoln's Sparrow						Y					Y		Y	R+	
MacGillivray's Warbler			N	H		Y					Y		Y		
Magnolia Warbler			N				Y	Y					A	Y	
Mountain Bluebird					Y				Sec			Y		Y	
Mountain Chickadee			R					Y	wP			Y			
Nashville Warbler			N				Y				Y		A	R+	
Northern Shrike					Y								A		
Northern Waterthrush			N	Shr		Y							Y		
Olive-sided Flycatcher			N		Y							Y	Y	Y	
Orange-crowned Warbler			N	M		Y									
Ovenbird			N				Y				Y		Y		
Pacific-slope Flycatcher								Y	(sec)?		Y		A		
Palm Warbler			N									Y			
Pine Siskin			(R)		Y							Y			
Purple Finch			(R)					Y				Y		Y	
Red Crossbill			R					Y				Y			
Red-breasted Nuthatch			R					Y	wP			Y			
Red-eyed Vireo			N	H		Y					Y				
Rose-breasted Grosbeak			N				Y				Y				
Ruby-crowned Kinglet								Y			Y				
Rusty Blackbird				M	Y								Y		
Say's Phoebe						Y								R+	
Song Sparrow				M		Y							A	Y	
Steller's Jay			R				Y	Y				Y			
Swainson's Thrush			N	H	Y						Y		Y		
Tennessee Warbler			N		Y								Y		

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Common Name[1]	COSEWIC[2]	BC[3]	Neo[4]	Shr[5]	G[6]	E[6]	M[6]	L[6]	Cavity[7]	DW[8]	Dec.[9]	Con.[9]	R[10]	Edg.[11]	Int.[12]
Townsend's Solitaire					Y					Y			Y		Y
Townsend's Warbler			N		Y							Y	Y		
Tree Swallow			N			Y			Sec						
Varied Thrush			(R)					Y				Y	Y		Y
Veery			N				Y						Y		
Violet-green Swallow			N			Y			Sec				Y	Y	
Warbling Vireo			N	M		Y					Y				
Western Kingbird			N		Y										
Western Tanager			N					Y				Y			
Western Wood-pewee			N		Y						Y		Y		
White-breasted Nuthatch			R					Y	wP						Y
White-crowned Sparrow				M	Y									Y	
White-throated Sparrow						Y	Y								
White-winged Crossbill			R					Y				Y			
Wilson's Warbler			N	Shr		Y					Y		Y	Y	
Winter Wren			(R)	Shr	Y				Sec	Y		Y			
Yellow Warbler			N	H		Y					Y		Y		
Yellow-bellied Flycatcher			N				Y					Y	Y		
Yellow-rumped Warbler						Y						Y	Y	R+	
MAMMALS															
Order Insectivora															
Common Shrew					Y					Y					
Dusky Shrew					Y					Y					
Pygmy Shrew					Y					Y					
Order Chiroptera															
Big Brown Bat					Y				Sec						
Hoary Bat								Y	Sec				Y		
Little Brown Myotis								Y	Sec		Y		Y	Y	
Long-legged Myotis								Y	Sec		Y			Y	
Silver-haired Bat								Y	Sec				Y		
Western Long-eared Myotis								Y	Sec				A		
Yuma Myotis								Y	Sec		Y		Y		
Order Lagomorpha															
Snowshoe Hare				S	Y						Y			R+	
Order Rodentia															
Beaver					Y						Y		Y		
Brown Lemming						Y									
Bushy-tailed Woodrat					Y								Y	Y	
Deer Mouse					Y					Y				Y	
Heather Vole						Y				Y	Y			R+	
Long-tailed Vole						Y				Y	Y		A		
Meadow Jumping Mouse						Y							Y		
Meadow Vole						Y									
Northern Bog Lemming						Y							A		
Northern Flying Squirrel								Y	Sec			Y			

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Common Name[1]	COSEWIC[2]	BC[3]	Neo[4]	Shr[5]	G[6]	E[6]	M[6]	L[6]	Cavity[7]	DW[8]	Dec.[9]	Con.[9]	R[10]	Edg.[11]	Int.[12]
Porcupine								Y	O				Y		
Red Squirrel								Y	Sec			Y			
Southern Red-backed Vole								Y		Y			Y		Y
Western Jumping Mouse				Shr		Y				Y	Y		A		
Yellow-pine Chipmunk					Y				O	Y		Y	Y		
Order Carnivora															
Black Bear					Y				O	O				Y	
Bobcat					Y					Y					
Cougar								Y			Y		Y		
Coyote					Y									R+	
Ermine					Y					Y			Y	Y	
Fisher		R						Y	Sec	Y			Y		Y
Gray Wolf					Y										
Grizzly Bear	SC	B			Y				O				Y		
Least Weasel					Y					Y					
Long-tailed Weasel					Y					Y			Y	R+	
Lynx								Y		Y	Y		Y	R+	
Marten								Y	Sec	Y		Y		Y	
Mink								Y		Y					
Red Fox					Y					Y					
River Otter					Y					?			Y		
Striped Skunk					Y								Y	R+	
Wolverine	SC	B						Y		O					
Order Artiodactyla															
Elk				Shr	Y								Y	Y	
Moose				Shr	Y								Y	Y	
Mule Deer (incl. Black-tailed deer)				Shr	Y									Y	
White-tailed Deer				Shr	Y								Y	Y	
Woodland Caribou (northern pop.)	T-SC[13]	B						Y					Y		Y
Woodland Caribou (southern pop.)	T	R						Y					Y		Y

[1] Species are ordered alphabetically by common name within families presented in conventional taxonomic order.

[2] National status designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC on line). T = Threatened; SC = Special Concern.

[3] "BC" indicates species status in the province of British Columbia; "R" denotes red listed;

"B", blue listed; as determined by the Conservation Data Centre of the B.C. Ministry of Environment; last updated in March 2004.

[4] "N" indicates species is a neotropical migrant; "R" indicates species is a resident; "(R)" indicates species is resident in parts of its BC range.

[5] Shrub nester; "H" indicates high requirement of shrubs for nesting; "M" indicates medium requirement of shrubs for nesting

Ehrlich et al. (1988); Campbell et al. (1990 a, b, 1997); "Shr" Indicates species closely associated with shrubs, but not a shrub nester.

[6] G = generalist species, showing little response to seral stage; species favored by particular seral stages are designated "E"(early), "M"(middle), and "L"(late).

[7] P = Primary Cavity Nester, wP = Weak Primary, Sec = Secondary Cavity Nester (obligate), Cv = Cave or Crevice (may use cavities, especially during winter), O = Opportunistic.

[8] "Y" = Use downed wood for reproduction and/or feeding.

[9] Strongly associated with deciduous (Dec.=Y) or coniferous (Con.=Y) Hagar et al. (1995); Campbell et al. (1990 a, b, 1997);

[10] Y = Riparian obligate; A = riparian associate.

[11] Y = statistically demonstrated to prefer edge ($p<0.05$); R+ = respond positively to edge (not statistically evaluated).

[12] Y = forest interior species, statistically demonstrated to avoid edge ($p<0.05$).

[13] Thirteen herds of the 'Northern' caribou population are found in the 'Southern Mountains' - a 'National Ecological Area' adopted by COSEWIC. Threatened status has been assigned by COSEWIC to all caribou in the Southern Mountain National Ecological Area. All remaining caribou have been assigned the status 'Special Concern'.

Appendix II. Fish Species Accounts.

Available online at: http://142.103.128.161/uploadedFiles/fish-species%20accounts.pdf

Appendix III. Native species of non forest-dwelling vertebrates occuring in mountain-pine beetle infested regions in British Columbia.

Common Name [1]	Scientific Name	COSEWIC [2]	BC [2]	Breeding Habitat [4]	Comments
MOSTLY AQUATIC					
Spotted Frog	*Rana pretiosa*			Ponds	Forages occasionaly in forested areas.
WETLANDS, LAKES and/or RIVERS					
Birds that breed or may breed in the three TSA area					
American Bittern	*Botaurus lentiginosus*		B	Wet	
American Coot	*Fulica americana*			Wet	
American White Pelican	*Pelecanus erythrorhynchos*	NaR	R	Isl	
American Wigeon	*Anas americana*			Upl	
Bank Swallow	*Riparia riparia*			Rip (banks)	Requires wetlands, but occurs in various habitat types including wetlands, meadows, agricultural land.
Belted Kingfisher	*Ceryle alcyon*			Rip	
Black Tern	*Chlidonias niger*			Wet	
Blue-winged Teal	*Anas discors*			Rip	
Bonaparte's Gull	*Larus philadelphia*			Upl-Isl	
Brewer's Blackbird	*Euphagus cyanocephalus*			Shrubs- Trees- Manmade	Occurs in various open habitats.
California Gull	*Larus californicus*		B		Migrant in BC. Requires wetlands, buta also occurs in agricultural and urban areas.
Canada Goose	*Branta canadensis*			Isl-Rip	Requires wetlands, but occurs in various habitat including urban, agriculture, and grassland areas.
Canvasback	*Aythya valesineria*			Wet	
Cinnamon Teal	*Anas cyanoptera*			Rip-Isl	No breeding records in area; It is at the northern limit of its breeeding range in south BC.
Common Loon	*Gavia immer*			Isl-Rip	
Common Snipe	*Gallinago gallinago*			Wet - Upl	Uses agricultural and urban areas.
Eared Grebe	*Podiceps nigricollis*			Wet	
Gadwall	*Anas strepera*			Wet- mead- flooded grassl	No breeding records in area.
Greater Yellowlegs	*Tringa melanoleuca*			Rip	Breeds in wet areas in forests
Herring Gull	*Larus argentatus*			Isl- Rock	Requires wetlands, but also occurs in agricultural and urban areas
Horned Grebe	*Podiceps auritus*			Wet	
Killdeer	*Charadrius vociferus*			Rip - Upl	Occurs in various habitat at all elevations.
Le Conte's Sparrow	*Ammodramus leconteii*			Wet	No breeding records in area.
Lesser Scaup	*Aythya affinis*			Isl- farm- mead- others	
Marsh Wren	*Cistothorus palustris*			Wet	
Northern Pintail	*Anas acuta*			Various	
Northern Shoveler	*Anas clypeata*			Rip- upl- grass	
Pacific Loon	*Gavia pacifica*			Isl	
Pied-billed Grebe	*Podilymbus podiceps*			Wet	
Redhead	*Aythya americana*			Wet	

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Red-necked Grebe	*Podiceps gricegena*			Wet	
Red-winged Blackbird	*Agelaius phoeniceus*			Wet	
Ring-billed Gull	*Larus delawarensis*			Isl	Requires wetlands, but also occurs in agricultural and urban areas
Ring-necked Duck	*Aythya collaris*			Wet-Rip	
Ruddy Duck	*Oxyura jamaicensis*			Wet	
Sandhill Crane	*Grus canadensis*	NaR	B	Wet-Isl-Mead	Requires wetlands, but also occurs in grasslands and agricultural areas.
Sora	*Porzana carolina*			Wet	
Spotted Sandpiper	*Actitis macularia*			Rip	
Western Grebe	*Aechmophorus occidentalis*			Wet	
White-winged Scoter	*Melanitta fusca*			Wet	
Wilson's Phalarope	*Phalaropus tricolor*			Wet	
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*			Wet	Uses grasslands and agricultural areas.

Birds that do not breeed but migrate through or visit the three TSA area

Arctic Tern	*Sterna paradisaea*	Rare autumn migrant in interior BC
Baird's Sandpiper	*Calidris bairdii*	Transient in BC. Does not breed in BC. Also occurs in alpine areas
Buff-breasted Sandpiper	*Tryngetes subrificollis*	Casual transient. Requires wetlands, but also occurs in grasslands/ agricultural and urban areas.
Dunlin	*Calidris alpina*	Winters in BC rare migrant in central BC
Glaucous Gull	*Larus hyperboreus*	Very rare winter visitant
Greater Scaup	*Aythya marila*	Does not breed in Area or BC - migrant.
Greater White-fronted Goose	*Anser albifrons*	Uncommon spring and autunm transiant in Interior. Does not breed in BC. Requires wetlands but also ocurs in grasslands.
Green-winged Teal	*Anas crecca*	Occurs in woodlands- rangelands- wetlands, and others.
Least Sandpiper	*Calidris minutilla*	Migrant in study area.
Lesser Golden-plover	*Pluvialis dominica*	Migrant throughout BC. Occurs in wetlands, grasslands, rangelands, and urban areas.
Lesser Yellowlegs	*Tringa flavipes*	Migrant in central BC
Long-billed Dowitcher	*Limnodromus scolopaceus*	Migrant in BC
Mew Gull	*Lrus canus*	Migrant in central BC
Oldsquaw	*Clangula hyemalis*	No breeding in area and BC. Sporadic wanderer in interior BC.
Pectoral Sandpiper	*Calidris melanotos*	Migrant in study area. Occurs in wetlands, rangelands, and urban areas.
Red-necked Phalarope	*Phalaropus lobatus*	Migrant in BC
Ross' Goose	*Chen rossii*	No breeding in BC. Very rare vagrant. Occurs in various open habitats.
Rudy Turnstone	*Arenaria interpres*	Migrant in BC
Sanderling	*Calidris alba*	Migrant in BC
Semipalmated Plover	*Charadrius semipalmatus*	Migrant in central BC
Semipalmated Sandpiper	*Calidris pusila*	Migrant in BC

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Snow Goose	*Chan caerulescens*				No breeding in BC. Migrant
Surf Scoter	*melanitta perspicillata*				Migrant and visitant in the interior. Breeds in northeast only.
Swamp Sparrow	*Melospiza georgiana*				Migrant and visitor in study area
Trumpeter Swan	*Cignus buccinator*		B	Wet-Rip	No breeding records in area.
Tundra Swan	*Cygnus columbianus*				Does not breed in BC. Migrant
Western Sandpiper	*Calidris mauri*				Migrant in BC
Mammals					
Muskrat	*Ondatra zibethicus*			Wet	Requires wetlands but also occurs in urban and agricultural areas.
Water Shrew	*Sorex palustrus*			Rip	

GRASSLAND/ MEADOWS/ AGRICULTURAL FIELD

Birds that breed or may breed in the three TSA area

Bobolink	*Dolichonyx oryzivorus*			Grassl	Occurs in grasslands and rangeland
Horned Lark	*Eremophila alpestris*			Grassl	Occurs in grasslands, rangeland, and alpine areas.
Long-biled Curlew	*Numenius americanus*	V	B	Grassl	No breeding records in area.
Savannah Sparrow	*Passerculus sandwichensis*			Various	Occurs in various open habitat at all elevations.
Short-eared Owl	*Asio flammeus*	SC	B	Grassl	No breeding records in area.
Vesper Sparrow	*Pooecetes gramineus*			Grassl	Occurs in grasslands, rangeland, and alpine areas.
Western Meadowlark	*Stunella neglecta*			Grassl	Occurs in grasslands and rangeland

Birds that do not breeed but migrate through or visit the three TSA area

Brambling	*Fringilla montifringilla*	Migrant in BC. Occurs in grasslands, agricultural fields, and riparian areas.
Brewer's Sparrow	*Spizella breweri*	Casual migrant in central BC. Occurs in grasslands and willow fields.
Hoary Redpoll	*Carduelis hornemanni*	Migrant in central BC. Occurs in grasslands and agricultural fields.
Smith's Longspur	*Calcarius pictus*	Migrant in most of BC
Snow Bunting	*Plectrophenax nivalis*	winters in BC.Occurs in grasslands, agricultural and mining fields, and along roads.

ALPINE
Birds

American Pipit	*Anthus rubescent*	Alp	Also occurs in various habitat at all elevations.
Gray-crowned Rosy-finch	*Leucosticte tephrocotis*	Alp	Occurs in grasslands, wetlands, and alpine areas.
Willow ptarmigan	*Lagopus lagopus*	Alp	

Mammals

Common Pika	*Ochoyona princeps*	Alp
Mountain Goat	*Oreamnos americanus*	Alp
Thinhorn sheep	*Ovis dalli*	Alp

Appendix III

MULTIPLE HABITAT USERS

Birds that breed or may breed in the three TSA area

Band-tailed Pidgeon	*Columba fasciata*	Various	Occurs in urban and agricultural areas.
Barn Swallow	*Hirundo rustica*	Manmade	Occurs in wetlands, and wooded, alpine and agriculture areas
Cliff Swallow	*Hirundo pyrrhonota*	Manmade- Cliffs	Occurs in varioushabitats.
European Starling	*Sturnus vulgaris*	Manmade- Woodlands	Occurs in urban and agricultural areas.
House Finch	*Carpodacus mexicanus*	Shrubs	Observed; Occurs in urban and agricultural areas.
House Sparrow	*Passer domesticus*	Manmade	Occurs in urban and agricultural areas.
Mallard	*Anas platyrhynchos*	Various	
Mourning Dove	*Zenaida macroura*	Various	Occurs in urban and agricultural areas.
Northern Harrier	*Circus cyaneus*	Wet- Grassl	Observed; Occurs in open areas at all elevations.
Northern Mockingbird	*Mimus polyglottos*	Shrubs	Observed; Occurs in wetlands, and urban and agricultural areas.
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	Manmade	Occurs in varioushabitats.

Birds that do not breeed but migrate through or visit the three TSA area

Common Gragle	*Quiscalus quiscula*		Migrant in study area. Occurs in wetlands, rangelands, and urban areas.
Lapland Longspur	*Calcarius lapponius*		Migrant in BC. Occurs in open habitats at all elevations.
Lark Sparrow	*Chondestes grammacus*		Rare migrant in central BC. Occurs in grasslands, and urban and agricultural areas.
Rough-legged Hawk	*Buteo lagopus*		Migrant and visitant in BC. Occurs in various open habitats.
Snowy Owl	*Nyctea scandiaca*		Visitant in BC. Occurs in open habitats at all elevations.

Mammals

Columbian Ground Squirrel	*Spermophilus columbianus*	Semi-fossorial	Occurs in various habitat at all elevations.
Hoary Marmot	*Marmota caligata*	Semi-fossorial	Occurs in various habitat at all elevations.
Woodchuck	*Marmota monax*	Semi-fossorial	Occurs in various open habitats.

OTHERS

American Goldfinch	*carduelis tristis*	Trees- Shrubs in agricultural areas	Does not nest in BC - Uncommon migrant in central BC. Edge habitat species.
Black Swift	*Cypseloides niger*	Cliffs	
Golden-mantled Ground Squirrel	*Spermophilus lateralis*	Rocky outcrop- Talus	

[1] Species are ordered alphabetically by common name.

[2] National status designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC on line). T = Threatened; SC = Special Concern.

[3] "BC" indicates species status in the province of British Columbia; "R" denotes red listed;

"B", blue listed; as determined by the Conservation Data Centre of the B.C. Ministry of Environment; last updated in March 2004.

[4] Breeding habitat. Wet=wetlands, lakes, and/or rivers; Rip= riparian; Upl=Uplands; grassl=grasslands.

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