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The Ecological Role of Beetle-Killed Trees:
A review of salvage impacts

By

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1. Purpose of Review

The purpose of this review is to provide an overview of the role beetle-killed stands play in contributing to ecological functions and processes in forested landscapes. The specific context of this review is to contribute to the information the Chief Forester will consider in his Annual Allowable Cut determination in the Lakes Forest District in response to a large mountain pine beetle infestation. District Ministry of Forests staff have recommended an increase in harvest level from 1,500,000 m^3 per year to 3,000,000 m^3 per year for 10 years to allow bark beetle control operations. In bark beetle outbreak areas forest managers need to assess the relative risks and benefits of salvaging beetle killed trees versus leaving these stands unmanaged. As only a few weeks were available to complete this review, it cannot be considered a thorough literature review and only reflects the subset of the literature that I was able to obtain during this time.

This review first discusses the role of mountain pine beetle in landscape disturbance ecology and how it influences natural successional pathways. The habitat attributes provided by bark beetle disturbances are then discussed along with the impact to these attributes by salvage harvesting. Finally, on the basis of this review, some conclusions and recommendations are provided.

2. Beetle disturbance and salvage effects on successional dynamics

The central interior of British Columbia is a dynamic landscape characterized by large stand replacing disturbance events of fires and insect outbreaks which have created a mosaic of forests varying in species composition, age class, and structure (McCullough, Werner, et al. 1998; Parish, et al. 1999). The frequency and extent of these disturbance events vary through time as they are related to a complex set of interrelated factors including year to year weather conditions, longer term climate trends, and stochastic events. Thus, the state of the forests will have varied considerably over time with periods where landscapes were alternately dominated by old or young forests with varying species and structural compositions. For example, while the forests in the sub-boreal spruce zone (SBS) are now predominantly old, the landscape 140 years ago was dominated by young seral stands (Steventon 1997). Whether these stands originated as a result of beetle infestations, or fire, or a combination of both is difficult to discern; what is clear is that the scale of the disturbance on this landscape at that time was large. The present mountain pine beetle infestation in the central interior is an example of this kind and scale of disturbance.

Insect infestations differ from fire in the successional pathways that forested ecosystems follow after these disturbances. Insect infestations favour succession of late seral species, usually shade tolerant species growing in the understorey; whereas fire removes this component and favours the re-establishment of early, shade intolerant species (Sinton et al. 2000). In the Lakes Forest District mountain pine beetle infestations would favour, on many sites, the succession to spruce-fir dominated forests (see Cole and Amman 1980;

Samman and Logan 2000). On other sites heavy mortality could favour grasses or other early seral species such as aspen (Stone and Wolfe 1996). In any case, the rate and direction of succession would be dependent on level of mortality, the level of advanced regeneration of spruce and fir in the understorey, and the rate of successful post-disturbance establishment of lodgepole pine (if any). These factors may be influenced by site or by history of earlier natural (*ibid.*) or anthropogenic disturbances (personal observations). An additional variable is fire disturbance. There is evidence from other locations of a linkage between beetle out-breaks and subsequent fire disturbance (see literature list in Fuchs 1999). The pattern of fire is unlikely to correlate precisely with the insect disturbance pattern resulting in a mosaic of insect and fire disturbed forests following different successional pathways.

Salvage operations in bark beetle disturbed areas would alter the post disturbance successional pathway from one favouring late seral shade tolerant species to one favouring more early seral shade intolerant species. Most forest management in the Lakes Forest District to date has created even-aged early seral forests. Increasing the rate of harvesting as proposed would add an additional ~60,000 hectares[1] to this habitat type at the expense of the already declining later seral habitats.

3. Beetles, salvage and forest structure

The impact of a bark beetle infestation on the ecological processes and functioning of a forest stand will vary depending on the degree of mortality within the stand. Degree of mortality depends on the intensity of the infestation and the proportion of non-susceptible trees in the stand. The surviving trees in the overstorey and understorey strata will provide some habitat characteristics from the pre-disturbance forest. These characteristics include live vertical structure and, depending on the level of survival, some thermal- and snow-interception cover. The advanced regeneration of usually shade tolerant trees in the understorey will also provide visual screening for wildlife and contribute to shade cover influencing micro-climate conditions on the forest floor.

Salvage operations would reduce the living mature/old and understorey components of the forest. The level of reduction of the living component of the pre-disturbance stands would depend on the silvicultural system utilized. Clearcut systems would result in the greatest reductions in both overstorey and understorey surviving trees. Overstorey removal would remove the mature/old stratum while protecting some of the understorey stratum. Patch cut and modified selective systems would protect to some degree a portion of both strata. However, any living tree retention in a salvage operation faces an increased susceptibility to blow down. Extensive blowdown of live tree retention has been observed in the Caribou Migration Corridor area of the Lakes Forest District where great care has been taken to maximize retention of live trees (personal observations 2000, 2001). As much of this blowdown has been of large spruce trees an increased risk of spruce bark beetle infestation is created. It thus appears that mitigation measures to maximize retention of live residuals in both overstorey and understorey strata in salvage

[1] 60,000 hectares based on the assumption of 1,500,000 m^3/year additional harvesting for 10 years at 300 m^3/hectare.

operations may not be fully successful. Live residual retention would be far greater in unsalvaged / unmanaged stands.

Standing dead trees or snags are created in large numbers through insect and fire disturbances. In fact these episodic disturbances are the dominant factor creating snags in many forests (Morrison and Raphael 1993) such as the pine stands of BC's central interior. Snags created by non-fire events remain standing longer than those killed by fire (ibid.). Raphael and Morrison (1987) speculated that fire disturbance events resulted in an excess of snags relative to wildlife needs. Their later work qualified this assertion indicating the importance of catastrophic events in landscape snag dynamics (Morrison and Raphael 1993). This indicates that aggressive salvage programs could affect long-term snag dynamics at a landscape or regional level.

4. *Wildlife use of post-disturbance and post salvage-logged forests*

Research specific to the wildlife use of post bark beetle disturbed forests is rare (Fuchs 1999). However there is some literature on wildlife use of habitats created by other insect infestations such as spruce budworm (e.g. Chapin et al. 1997; Payer and Harrison 2000; Hudak and Raske 1981). There is a more abundant body of literature on the utilization of post fire habitats (see literature review in McIver and Starr 2000). While the habitats created by other insect infestations more closely approximates those created by bark beetles, post fire habitats have many characteristics in common with post bark beetle disturbance habitats. Intense bark beetle outbreaks and fire both create large numbers of standing dead snags, and both dramatically reduce live crown closure. As discussed above fire disturbance has a greater effect on successional dynamics than bark beetle disturbance as crown fire destroys both overstorey and understorey strata and therefore impacts on wildlife use would also be expected to be greater. With this proviso in mind, it is still useful to also look at wildlife use of post-fire habitats in order to get some idea of the wildlife value of post-beetle habitats.

American marten avoid recently salvaged spruce budworm stands when establishing territories but do not avoid similarly aged unsalvaged stands with extensive tree mortality caused by spruce budworm (Payer and Harrison 2000). The salvaged stands have reduced cover of understorey vegetation and downed logs resulting in lower abundances of small mammal prey species than the unsalvaged areas (Bull and Blumton 1999; Chapin et al. 1997).

Coarse woody debris (CWD) plays a well documented role in the ecological processes of forested systems (Stevens 1997, Keisker 2000). CWD provides habitat for small mammals (Bowman, et al. 2000), amphibians (Waldick, et al. 1999; Butts and McComb 2000), arthropods (see review in Stevens 1997), and nonvascular plants and fungi (Crites and Dale 1998; Kruys and Jonsson 2000). Bark beetle infestations are an important source of CWD in the central interior of BC which results in great variations in the rate of CWD input over time (Clark, et al. 1998). Inputs of CWD are reduced in managed forests as the larger diameter logs are removed from the system. Salvage of fire and beetle-killed trees removes an important episodic source of CWD (*ibid.*).

Post fire salvage logging reduces denning and travel habitat for lynx and the long term reduction of CWD reduces the habitat for snowshoe hares, a major prey of lynx (United States Forest Service 1995).

The large numbers of standing dead trees created by a bark beetle infestation provide habitat for woodpeckers and other cavity nesting birds (Parks et al 1999; Bull et al. 1997). Salvaged stands differ from unsalvaged burns by the absence of cavity nesting birds such as black-backed woodpecker, three-toed woodpecker, and brown creeper (Imbeau et al. 1999). Species that are very specialized in using post-disturbance habitats such as black-backed woodpecker are considered particularly vulnerable to local/regional extinction with programs of fire suppression and intensive salvage logging (Hutto 1995; Murphy and Lehnhausen 1998; Hobson and Schieck 1999; Schieck and Hobson 2000). Bark-beetle killed trees have greater value for cavity nesting birds than fire-killed trees as they are not case-hardened by fire and are more conducive to wood softening decays (Bull et al. 1997).

The removal of large forest structure in salvage harvesting shifts species composition to species preferring more open habitat (Blake 1982, McIver and Starr 2000). Post-fire salvage reduces hiding cover for deer by suppressing shrub cover (Grifantini, et al. 1991, cited in McIver and Starr 2000). However, salvage harvesting could increase the availability of young seral forage for ungulates such as moose, deer, and elk (Schuerholz, et al. 1988). Thus salvage of beetle killed trees would negatively impact species which utilize habitats dependent on old/mature forest features and favour species which primarily utilize more open, young seral forest habitats.

Fish habitat could be affected by increases in peak flows and storm flow volumes that have been documented following post fire salvage logging (Mackay and Cornish 1982). Some of this impact may be created by road development which is discussed below.

5. *Impacts of roads on wildlife and habitats*

One significant difference between salvaged and unsalvaged landscapes will be the development of access structures. If salvage is to occur in landscapes that are presently unaccessed a network of access structures will need to be developed. In more developed landscapes, salvage logging will require the reactivation of old roads, result in increased traffic on existing roads, in addition to the development of new spur roads.

Road development creates one of the more significant impacts on environmental values associated with forest harvesting (Noss 1995). Roads affect terrestrial and aquatic ecosystems by increasing mortality from construction and collisions, modifying animal behaviour, altering the physical environment, facilitating spread of exotic species, and increasing the alteration and use of habitats by people (Trombulak and Frissell 2000). Roads are a greater contributor to habitat fragmentation than other aspects of forest harvesting and thus have significant impacts on habitat connectivity and quality (Reed et al. 1996). The linear corridors created by roads can result in altered predator-prey dynamics by improving the hunting efficiency of predators (James and Stuart-Smith 2000). This effect continues even with full deactivation of roads. Caribou are particularly sensitive to altered predator-prey relationships. Human hunting pressure is also increased with greater road density on a landscape. Grizzly bear, wolves, wolverine, fisher, lynx, and caribou are all negatively affected by road development associated with salvage operations (Frederick 1991; Ruggiero et al. 1994, United States Forest Service 1995; James and Stuart-Smith 2000).

Roads also create significant impacts on streams and aquatic habitats (Furniss et al. 1991). They can change the hydrology of a watershed and affect peak and low flows (Jones et al. 1996, 2000). In salvage operations after fire the increased use of existing roads can be the greatest contributor to post-fire erosion (Megahan 1980).

6. Does harvesting protect wildlife habitat in beetle infestations?

This review has so far assumed that forest harvesting in a bark beetle infestation is directed at reducing unsalvageable losses of timber and that reduction of infestation spread and ultimate level of tree mortality is not achieved. It is necessary to validate this assumption at this point. If harvesting of beetle infested trees could control the infestation and protect significant areas of forest from being impacted, an argument could be made that aggressive directed harvest could benefit wildlife habitat values by increasing the diversity of habitats following the infestation. In this scenario, rather than having the landscape dominated by beetle killed forests, the landscape would contain a mix of beetle disturbed and undisturbed forests and species dependent on the latter habitats would be better accommodated.

Is it possible to control bark beetle infestations? As the infestation spread rate increases, the proportion of trees infected that must be treated to be successful in control activities also increases. For example at a rate of spread of ~1.5:1 (see footnote for explanation of spread ratio[2]) only 20% of infested trees need to be treated to be successful. However the required treatment rate increases to ~60% for 2:1 spread ratios and exceeds 80% at ratios above 4:1 (Les Safranyik 2000, personal communication 2001). The current rate of spread of the infestation in the Lakes Forest District is likely already exceeding 2:1 and may very well be approaching or exceeding 4:1 (Lakes Forest District staff 2001). Thus, at least 60% and perhaps over 80% of infested trees require treatment if this infestation is to be suppressed. Treatment rates below these percentage will not have any effect on extent of infestation induced mortality but may extend the length of the infestation. If the period of the infestation were extended there is an increased possibility of natural cold-weather events occurring that could end the infestation.

It can be concluded that the increased rate of forest harvesting proposed in the Lakes Forest District will almost certainly not be sufficient to suppress the mountain pine beetle infestation. There is an undetermined possibility of reduced tree mortality if this increased harvest rate also increases the infestation period and if an infestation-ending

[2] Ratio expresses the number of newly infested trees per tree infested one year ago. For example a 2:1 ration indicates that for every tree infested the year before, there are now 2 infested trees.

weather event occurs within this period. In determining the relative risk to wildlife habitat through increased salvage harvesting this undetermined possibility of salvaging benefiting wildlife habitat values must be assessed against the more certain negative effects documented in the previous sections.

7. Conclusion

Acceleration in harvest rates increases the shift to young seral and open habitats from more complex habitats with older forest characteristics. This latter habitat type is already being reduced under current management regimes and increased harvesting will cause further reductions. Loss of live and dead structure, shifting of successional pathways, and the impacts of increased density of access structures will all negatively affect species that are already negatively affected by current operations. Species that are well adapted to young managed forests already benefit from current management strategies and will likely benefit further from accelerated harvest rates. Thus the ecological benefit of not harvesting beetle killed trees is that this allows the natural processes of death, decay, regeneration and maturity to continue and provides the habitats for species dependent on those processes.

The possibility exists that wildlife habitat diversity could benefit if harvesting were to "save" some areas from beetle impact. However, the probability of this occurring is unknown and must be assessed against the negative effects of increased road density and reduced old-forest structure.

Therefore, from a ecological perspective, increasing harvest rates to salvage beetle killed trees increases the risk of negative impacts to the diversity of wildlife and wildlife habitat.

8. Recommendations

Information of future habitat supply is needed to assess the degree of risk to wildlife and wildlife habitat through increased harvest rates. What will be the supply and quality of wildlife habitat under various harvest and disturbance scenarios? In order to answer these questions both habitat and timber supply models will require a better understanding of successional dynamics following beetle disturbance. For example, we need to better understand the level of tree survival in beetle infested stands as well as the degree, composition, and rate of natural regeneration in these stands. Habitat supply analyses also require some form of ecosystem mapping from which wildlife habitat interpretations can be made. Once a better understanding of long-term habitat supply impacts is obtained, better decisions can be made on ecologically appropriate longer-term salvage patterns and rates.

If a decision is made to proceed with an increased level of harvesting to salvage beetle killed trees, some of the negative impacts to wildlife can be reduced through aggressive access management and deactivation. The impact of roads and other access structures is one of the more negative impacts associated with forest harvesting (see discussion in section 5). The objective of this access deactivation would be to deconstruct the additional roads and trails created for salvage purposes and remove the linear corridors they created. Strategies to achieve this objective include recontouring and replanting of roads. In the longer term this would greatly reduce the hydrological and access related impacts otherwise created by increased road density. However, this strategy will only limit negative effects as in the short-term (the period of active salvage harvesting) an increased density of active access structures will be present.

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