APPENDIX B

Moose Post-Fire Project EIS
Post-Fire Mortality Estimation Guidelines

Introduction

Recognizing and predicting which trees a fire directly or indirectly kills is not an exact science. Obviously, a tree that has all its foliage and branches consumed by the fire is simple to categorize as dead. However, trees with varying amounts and kinds of fire injury, and their probability of dying within a few years as a direct result of this injury or of associated mortality factors (such as insect infestation), is a more difficult call. Realistically, no amount of scientific data will be able to tell us with certainty which trees will live or die, or how long they may live. But management can reliably estimate the likelihood of mortality, sufficient to make management decisions, based on parameters that we can measure and observe. To assist managers with this issue, and to provide direction for proposed treatments in the Moose Post-fire project, the guidelines outlined in this report have been developed.

The major information sources include research publications, guidelines developed in other areas and professional experience and observations by fire and vegetation managers on this forest. Refer to references listed at the end of this document.

Factors affecting tree survival after fire

Coniferous tree species vary widely in their resistance to fire injury. Factors influencing fire tolerance include:

- Bark thickness and character
- Branching habit as it affects crown openness and height of the lowest branches
- Flammability of the foliage
- Characteristics and protection of the buds
- Depth of rooting system

Though these characteristics affect a tree's resistance to injury, there is no conclusive evidence that the likelihood of mortality differs between trees with the same relative level of injury (Ryan and Reinhardt 1988). Once fire injures a tree, a complex of factors determines whether the tree survives or not. These include the tree's pre-fire physiological condition; the type and extent of injury; time of the fire in relation to growing season; site productivity; weather in the years following the fire; a host of potentially damaging biotic agents such as bark beetles and fungi; and interactions between all of them (FHP 2000, Weatherby et al 2001, Scott et al 1996, Ryan and Reinhardt 1988).

Primary variables explored in the research literature and shown to have substantial influence on tree survival following wildfire are crown scorch/kill and bole damage. These readily measurable variables will be the main factors focused on in these Moose Post-fire project guidelines. Damage to root systems of trees (i.e. the coarse and fine "feeder" roots near the surface of the soil) also contributes to tree mortality; however effects on roots have only been partially studied in the literature, and from a practical standpoint it is very difficult to directly measure in the field (Scott et al 1996). Possible root injury will be considered as one of the additional influencing factors in these guidelines.

Crown damage/crown kill (the % of live crown killed by the fire):

Crown damage is a key mortality indicator because it is easy to detect, physiologically important, and often the most severe form of injury (Ryan 1982, Ryan et al 1988). Crown kill is often apparent by the end of the first growing season after the fire by observing the presence or lack of new growth on the tree. Crown scorch (browned needles) immediately after the fire is not always an accurate predictor of the proportion of crown actually killed because of the tolerance of some species to scorch. For example, ponderosa pine has buds that are large and well protected from heat damage and may survive even if all needles are scorched. Larch has an open, heat-dissipating crown in addition to the ability to grow an entire new complement of foliage every year (if the buds are still alive).

Crown kill is calculated by:

1. Visually estimating the original pre-fire live crown length
2. Visually estimating the remaining post-fire live crown length (twigs and buds still alive the first growing season after the fire, which are often irregularly dispersed or on only parts of the branch length)
3. Calculating the percent of remaining live crown length =

   "remaining live crown length (feet)" ÷ "original live crown length (feet)"

Some hints for determining crown kill include using binoculars to check naked eye impressions; observing on clear days and viewing from the side on which the sun is shining if possible. The lee side of the crown (relative to the direction of the fire run) is usually the least damaged.

A volume estimate of live crown is often cited in the research literature, rather than the linear estimate described above. However, observing and calculating a linear estimate of crown damage is felt to be an easier and more accurate measurement to make for broad scale practical application of these guidelines at the project level. It is similar to volume estimates, and in any case a linear estimate would be more conservative than a volume estimate because of the conical shape of a typical tree crown, with the disproportionate share of volume located in the lower portions of the crown.

In the absence of other injury, low percentages of crown kill (i.e. < 30) are not usually considered serious (Ryan 1982, Ryan et al 1988). A crown kill greater than 70%, however, has usually caused substantial physiological stress and more likely than not the tree will die within five years (Weatherby et al 2001, Ryan 1982, 1988). Survival rates can vary widely, because many interrelated factors ultimately influence tree survival. This includes but is not limited to the degree of other fire injury to the tree; its susceptibility to insect and pathogens; individual tree characteristics such as vigor and size; and various abiotic factors, such as weather and site productivity (Ryan and Reinhardt 1988, Scott et al 1996). For example, larger older trees in some cases seem able to tolerate more crown scorch, perhaps because of their greater volume of foliage; however for some species (particularly Douglas-fir) these larger trees are also far more susceptible to beetle attack even at low levels of crown scorch (Furniss 1965, Ryan 1982, Peterson 1984, Rasmussen et al 1996, Ryan & Amman 1996, FHP 2000, Weatherby 2001). On the other hand, smaller, immature but vigorous trees sometimes have a better chance of surviving a given proportion of crown injury than older, slower-growing trees because of their greater ability to recover (Ryan 1988). Of course, crown damage alone does not tell the whole story and other factors, such as bole or root injury, need to be evaluated as well. For example, thin barked tree species that experienced a low severity ground fire may have crowns with no scorch whatsoever. However, these trees have very often been killed by fire damage to the roots or cambium at ground level, completely girdling the tree.

Bole/root crown damage (the % of the bole/root crown circumference killed by fire):

The primary factors controlling the likelihood of bole injury are the fire's duration and the tree's bark thickness (Ryan 1988). Older trees of thick barked species (Douglas-fir, larch and ponderosa pine) have the greatest resistance and can withstand longer duration and hotter fire intensities. Thin barked species (spruce, subalpine fir and lodgepole pine) are much more susceptible to cambial damage with even low intensity fire.

Some quantification of the relationship of actual measured cambium injury on tree survival has been documented, but it is limited (Wagener 1961, Ryan et al 1988). Computed bark thickness (as related to tree species and diameter) and the degree of char on the bole are more often used as a predictor of tree mortality, because they are more readily observed and measured (Ryan & Reinhardt 1988). As indirect measures of cambial damage, they are more subject to error and thus should be used cautiously. But they have been successfully used as mortality indicators (Wagener 1961, Peterson 1984, Ryan & Reinhardt 1988, Scott et all 1996, Weatherby 2001).

Mortality from bole injury is often not apparent immediately or even one year after the fire (Weatherby et al 2001). Water from the root system may still be able to be transported through xylem tissue up to the foliage, allowing photosynthesis to continue. However, with the dead cambium (phloem cells), no nutrients can be transported from the foliage back down to the roots, and the tree will soon die from lack of nourishment In addition, it may take

several years for thick bark over killed cambium to slough off and underlying damage to be apparent (Ryan 1982). Mortality associated with bole/root crown damage may result from a combination of factors, including direct fire injury, decay/mechanical weakness, and predisposition to insects.

Damage to the cambium of the stem or root crown is best determined by chopping through the bark and into the cambium at four points (quadrants) around the bole of the tree. Noting the appearance of the blackened, charred bole can provide an indirect measure. Deep damage to the stem is typically characterized by bark that is deeply charred around the base and lower bole (but not necessarily to the wood) and by bark that has largely lost its surface characteristics. Additional signs include: loss of bark color within the deep fissures of older trees, portions of the bark burned off, large fuels burned at the base of the tree, and bole scorch running high in the tree. Dead cambium is typically dry and discolored or darkened, versus live cambium, which will be moist to the touch and usually a light, milky white or pinkish/tan in color. Resin flow from bark or exposed wood between the bark and cambium can be an indicator as well (Wagener 1961, Ryan 1982). It helps to know that damage is ordinarily heaviest on the lee side of the tree and on the uphill side, and that killed patches of cambium are usually widest just above ground level and taper upward.

Tree species and diameter/bark thickness must be considered along with the visual indicators listed above. For example, thick barked trees can show substantial bark charring but still have live cambium underneath. Thin barked species, such as spruce or subalpine fir, may have dead cambium under relatively lightly charred bark.

Consideration of fire damage to the root crown and visible surface roots is part of this evaluation of cambial damage. Severe root damage from surface fire can occur in Douglas-fir, which often develop large, lateral roots close to and above the soil surface. Though the bark on the bole of Douglas-fir can be quite thick and fire resistant, these lateral roots have thinner bark and are easily damaged, even under a low severity ground fire.

Most research and observations indicate that trees with dead cambium in more than two quadrants (>50% of bole circumference) are poor candidates for survival (Ryan et al 1988). In many cases, cambium injury in more than one quadrant (>25% of the bole) was found to substantially lower tree survival. This is a threshold used in several existing mortality guidelines (Wagener 1961, Ryan et al 1988, Ryan 1990, Weatherby et al 2001, Kootenai NF 1995, Bitterroot NF 2001). As described earlier under crown kill, the interaction of other factors with cambium damage, such as degree of other types of fire damage, susceptibility of the tree to insects or pathogens, tree vigor, etc, exert a substantial influence on the tree's probability of surviving. This is particularly important to remember in the case of Douglas-fir in the Moose Post-Fire project. Even relatively light bole injuries in Douglas-fir when associated with small volumes of crown scorch, can still be moderately attractive to Douglas-fir beetles, especially if beetle populations are abnormally high before the fire (Furniss 1965, Scott et al 1996, Rasmussen et al 1996, Weatherby et al 2001).

Application to proposed action and its alternatives

The two main purposes for the proposed salvage actions in the Moose Post-Fire Project are to decrease potential mortality caused by bark beetles to live trees within and outside the fire area, and to recover merchantable wood fiber to support local communities and contribute to long term yield of forest products. Important resource objectives that are considered include retaining forest structural elements at desired levels (snags, downed wood, living trees), protecting soil productivity, and providing for the needs of wildlife species that live within, and in some cases benefit from, the fire-changed landscape.

With these purposes and objectives in mind, treatment prescriptions were developed for proposed salvage units within the Moose Post-Fire Project. These are described in full in the EIS (Chapter 2) and in Appendix A of the EIS. Prescription elements include the removal of most dead and dying trees – those not likely to survive the effects of the fire (defined as < 50% probability). Prescriptions specify the retention of trees within all salvage units that are currently live and have a good probability (defined as >50%) of surviving. Mortality may occur directly because of the fire injury, or due to other related factors, such as bark beetle infestation in Doulgas-fir. As much of the literature confirms, this form of post-fire mortality often has a substantial impact on Douglas-fir (Furniss 1965, Ryan 1982, Ryan 1988, Ryan et al 1988, Ryan & Reinhardt 1988, Amman & Ryan 1991, Rasmussen et al 1996, FHP 2000,

Flanagan 2001, Weatherby 2001). The documentation in this report is intended to provide the guidance and criteria to be used to identify the trees to be salvaged (the dead and dying) and the trees to be left.

There are also additional leave tree retention requirements specific to certain units or to an alternative to meet snag habitat objectives, management area guidelines, issues and concerns, etc. For example, units within non-suitable management areas (MA 13A) or within Inventoried Roadless areas and the Wild and Scenic River corridor have special salvage and leave tree requirements, and would remove trees only if infested with bark beetles. All other trees would be left on site. The guidelines in this document would not be used in these units.

The estimated mortality risk determinations in Tables 1 through 3 below use the variables of species, diameter (DBH), crown kill (percent remaining live crown) and estimated cambium kill, as described earlier in this report. If one of the Moose Post-Fire Project action alternatives is chosen, these tables would be applied in the implementation of salvage harvest to determine the trees that are most likely to survive the effects of fire injuries. These “live” trees would be left within all salvage units, as per the silvicultural prescription. In reverse, the criteria outlined in the table would also identify those trees most likely to die (particularly Douglas-fir with its susceptibility to bark beetles) and thus be salvaged, unless left to meet specific leave snag, forest structure, or other resource objectives.

Two things are particularly important to understand regarding these guidelines. First, the criteria (live crown length, cambial damage) are estimates made by trained field personnel. Exact measurements are not expected or necessary, though the estimates are expected to be accurate to within +-15%. Exploratory sampling through the bark with an axe of a representative sample of trees should be used to provide for reasonably accurate judgments regarding cambial injury in trees of different bole scorch character, species, and size classes. Instruments such as clinometers should also be used to train the eye for judgments regarding crown kill, and in borderline situations.

Second, the variables and predictions in the guidelines are associated with considerable variability and are drawn from diverse sources of information. They are based on probabilities, not absolute certainty, and draw upon the scientific information where it exists, as well as professional experience and judgment in the context of the site-specific situation in the project area. The guidelines as developed are felt to be rather conservative, erring on the side of leaving trees that might die, rather than taking trees that might live.

Tables 1 through 4 below outline the post-fire mortality guidelines. Species are listed in order of general tolerance to fire. An “X” indicates a tree that is either directly killed by the fire or is predicted to die within 3-5 years (>50% chance). Guidelines take into account the situation specific to the Moose Fire project area and the purpose and need for the proposed action. For example, because of the high, epidemic population level of Douglas-fir beetles in this area, the vulnerability of fire-injured Douglas-fir to bark beetle mortality in these next few years is believed to be higher than average.

Guidelines should be applied by first inspecting the crown, referring to Table 1, and if needed inspect the bole and estimate cambium damage, referring to Tables 2 and 3. The influencing factors listed in Table 4 should be considered before making a final judgment call, particularly in questionable or less obvious situations.

Table 1: Post-fire mortality risk considering remaining live crown (Step 1)

Species	D.B.H.	Remaining live crown length <= 10%	Remaining live crown length 20-40%	Remaining live crown length > 40%
Ponderosa pine	< 14” >=14”	X X	Go to Table 2 Go to Table 2	Go to Table 2
Larch	< 14” >=14”	X X	X Go to Table 2	
Douglas-fir	< 14” >=14”	X X	X X	
Lodgepole & white pine	< 14” >=14”	X X	X X	Go to Table 3
All other spp. (subalpine fir, spruce)	ALL SIZES	X	X	

Table 2: Post-fire mortality risk considering cambium damage (Step 2) for ponderosa pine, larch and Douglas-fir

		Cambium damage > 50% of bole/root crown circumference	Cambium damage 25-50% of bole/root crown circumference	Cambium damage < 25% of bole/root crown circumference
Ponderosa pine	< 14” >=14”	X X		
Larch	< 14” >=14”	X X		
Douglas-fir	< 14” >=14”	X X	X X	

Table 3: Post-fire mortality risk considering cambium damage (Step 2) for lodgepole pine, white pine, spruce and subalpine fir

		Cambium damage > 25% of bole/root crown circumference	Cambium damage <= 25% of bole/root crown circumference
Lodgepole & white pine	< 14” >=14”	X X	
All other spp. (subalpine fir, Spruce)	ALL SIZES	X	

(NOTE: An “X” in the tables above indicate a tree predicted to die from the effects of the fire (>50% probability)

Table 4: Influencing factors that should be considered, particularly in borderline or questionable situations, and in the evaluation of all Douglas-fir trees

1. Presence of bark beetle attacks (mainly in DF and PP). Inspect bole for any boring dust, frass, pitch tubes, galleries, etc.
2. Tree species and diameter. Consider fire tolerance of trees (i.e. larch, DF and PP vs. spruce), and age/size in relation to the bark thickness. Consider trees above 20” DBH probably have higher chance of surviving given a certain amount of damage relative to trees 16” DBH or smaller, unless they are Douglas-fir, in which case they are more likely to be attacked by bark beetles.
3. Post-fire crown condition/ratio. The higher the crown ratio, the higher the probability of survival.
4. Pre-fire tree vigor. The greater the vigor of the tree prior to the fire, the greater probability of surviving low or moderate fire injury.
5. Intensity of fire in the surrounding area and immediately around the tree. Aids in the evaluation of possible cambium/root damage. Shallow rooted species particularly susceptible to damage of small feeder roots close to soil surface include subalpine fir and spruce. White pine is moderately susceptible. Douglas-fir with large lateral roots at or above the soil surface is susceptible as well. Look for amount of soil exposure (degree the duff/organic soil layers have been consumed), concentrations of burned debris near the tree bole, the duration the fire burned near the tree, etc.
6. Presence of multiple stresses on trees, i.e. drought, mechanical damage, insects/pathogens (particularly root disease in DF), etc

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