Fire Effects on Rangeland
FACTSHEET

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Fire Effects on Trees and Shrubs

This factsheet will focus on how fire affects trees and shrubs. Fire is a dynamic process that affects grass and forbs in a variety of different ways. When determining the effects of fire on individual species and ecosystems, it is important to understand the condition of the plant community and individual species before a fire occurs. That is, the impact of fire on an individual plant species or communities may increase if the community has been subjected to other disturbances such as drought, disease, insect infestations, overgrazing, or a combination of these factors.

The response of trees and shrubs to fire varies significantly between and within species, and is dependant on the parameter being measured. Moreover, this response is influenced by a variety of fire parameters including intensity, severity (e.g., amount of organic matter consumed), residence time, soil heating, season of burn, and time since last fire, all of which can vary significantly among fires and within a fire. These variations will cause differences in how individuals and the community as a whole respond. In addition, numerous physical and climatic factors (e.g., fuel condition, weather, slope, and aspect) as well as biological factors (plant morphology and physiology) also influence post-fire effects on plant communities. This includes direct effects such as the ability of individual species to resist the heat of a fire (depending on age and seasonality) and the mechanisms by which they recover after fire.

In addition to fire parameters and individual species response, numerous external factors such as post-fire weather, post-fire animal use, and plant competition, can also determine how the grassland and individual species will respond to a fire. Common effects include plant mortality, increased flowering, seed production and numerous communal affects.

INDIVIDUAL PLANT TISSUE

Numerous studies have attempted to define the temperature required to kill vascular plant tissue. A temperature of 60^{o}C has been considered as a reasonable approximation of a lethal temperature required to kill shoot tissues of land plants, while others reported temperatures as low as 45^{o}C resulted in tissue death. Other, more recent publications, described 50 to 55 ^{o}C as being the temperature that typically results in tissue death. In general, the likelihood of plant tissue being killed is dependant on the amount of heat it receives, which is described as being the combination of the temperature reached and the duration of exposure.

Overall, it appears that individual plant mortality can occur at high temperatures over a short period as well as low temperatures over longer periods with individual plant sensitivity varying, depending on season. For example, growing points are often considered more sensitive to heat when they are actively growing and their moisture content is high.

FIRE EFFECTS ON INDIVIDUAL SHRUBS

Seasonality (e.g., moisture content), site characteristics (e.g., fuel loading), geographic and climatic factors all play an integral role in determining fire intensity and severity and, when combined with plant morphology, all influence the impact of fire on shrubs. Whether or not this impact is negative or positive is species dependant, with many species experiencing both positive and negative effects depending on fire severity. Seasonality affects fire severity by influencing the moisture content in the target plant and in the fuels surrounding the plant. In general, as moisture content of bark, leaves and twigs increases, so does the amount of heat required to raise them to ignition temperature. Moisture content typically varies throughout the growing season with highest levels being reached during active leaf formation and shoot elongation, declining to a lower level for the remainder of the growing season and then declining further following dormancy. Although it often takes a greater amount of heat to ignite a fire in the spring and early summer (often not the case in central to northern BC), this is generally when shrubs have utilized the majority of their energy reserves (to facilitate new growth) and thus are most vulnerable to fire. Thus, if a fire occurs during this time, there may be inadequate energy reserves to promote new growth. If fire occurs during or immediately following dormancy however, shrubs are typically more tolerant due to their ability to spend the majority of the growing season accumulating energy reserves (via photosynthesis), and thus if not severely damaged are more likely to sprout during the following spring. Various other morphological characteristics also determine a shrubs vulnerability to fire including crown size and shape, height, branch density, ratio of live to dead crown material, crown base location with respect to surface fuels, and total crown size. Other morphological characteristics including bud and branch size also influence the impact of fire on a shrub. In general, small buds and branches, due to their small mass and high surface area to volume ratios, are more susceptible to lethal heating than large buds.

How a fire impacts a shrubs stem (cambium tissue) is generally dependant on the protective quality of bark, which is determined by its thickness, composition, cracks, and moisture content, all of which influence the bark's ability to absorb and transmit heat. Bark thickness is generally species specific and dependant on various factors including shrub diameter and age, distance aboveground, site characteristics, and shrub health and vigour. As with trees, bark thickness varies with age with younger shrubs, because of their thin bark, being more vulnerable to fire than older plants. Since most shrubs have relatively thin bark, any charring will typically result in shrub death. Depending on severity, fire can also cause root mortality, that is, as fire severity increases so does root mortality. Typically, root damage will accompany stem damage and thus cause cumulative impacts on a shrub. Root damage or mortality can also occur however, when there is little or no apparent crown damage and can be significant enough to cause shrub mortality. In general, shrub survival is typically determined by flame length, fire severity including flaming residence time, and stem char height with most shrubs typically only surviving fires of low severity or fires that fail to result in significant crown, root damage or cambium damage.

Overall, fire typically affects shrubs by opening stands and rejuvenating sprouting shrubs such as saskatoon, chokecherry, mock orange, snowberry and rabbitbrush whereas weaker sprouting species including antelope bitterbrush, and various Eriogonum species typically take years to recover. Non-sprouting species, such as big sagebrush, which reproduce solely by seed, can be effectively removed from a system if their growing points are either consumed or exposed to lethal temperatures.

FIRE EFFECTS ON INDIVIDUAL TREES

Individual tree and shrub mortality typically occurs when several plant parts are damaged. For example, crown damage combined with a significant amount of cambium and/or root damage is more likely to result in death than if only one of these components was damaged. During intense/severe fires, tree and shrub mortality may be instantaneous. Under less severe situations, death may not occur or be delayed several years. Where death is delayed several years, it is often caused by secondary disturbances, such as infections by insects and pathogens that are able to enter the tree or shrub either due to decreased resistance or thru the provision of entry points (wound sites).

Fire effects on individual trees is dependant on tree age as well as numerous adaptations including germination, rapid growth and development, fire resistant bark and foliage, adventitious or latent growing points and serotinous cones, all of which have the ability to influence post-fire plant community dynamics. In general, as a tree increases in age, so does its resistance to fire as plant tolerance is generally correlated to increased crown size, stem diameter, and bark thickness as well as an increase in the height from the base to the live crown. The age at which a tree develops these attributes is dependant on tree species as well as site conditions. For example, trees subjected to poor conditions often take longer to develop fire resistance characteristics than those growing under ideal conditions. Germination adaptations can include hard-coated seeds or serotinous cones that lie dormant until a fire passes and the seed is scarified, while rapid growth and development adaptations can include adventitious or latent axillary buds that allow a plant species to complete its life cycle quickly and disperse seed in the event of two closely spaced fires. In general, fire-resistant foliage and bark have the greatest influence in determining plant survival. Combinations of these characteristics determine how a tree responds to a fire.

Did you know?
A serotinous cone is a cone that may be opened by the heat of fire thus allowing the cone to release its seeds(e.g., lodgepole pine)

An axillary bud is a growing point (bud) that occurs in an axil (where the leaf joins the stem) of a leaf.

For example, how fire impacts a tree's crown is influenced by seasonality, tree morphology and foliage characteristics. Seasonality, particularly moisture content, plays an integral role in determining fire severity and intensity. In general, as moisture content of leaves and twigs increase, so does the amount of heat required to raise them to ignition temperature. Tree moisture content varies throughout the growing season with highest levels being reached during active leaf formation and shoot elongation, declining further to a lower level for the remainder of the growing season, and then declining again following dormancy. In conifers, new foliage generally follows this pattern, whereas moisture levels in older foliage typically drop in the spring and rise in the late spring or early summer. These characteristics generally make conifers vulnerable to spring fires since, while the moisture content of the new tissue is the highest, it is the lowest in old foliage, and thus the overall flammability is increased. Deciduous trees however, tend to be vulnerable throughout the growing season and tolerant during dormancy. Various other morphological characteristics also determine a tree's vulnerability to fire including crown size and shape, tree height, branch density, ratio of live to dead crown material, crown base location with respect to surface fuels, and total crown size. For example, the aerial portions of small stature species are usually killed whereas larger trees, especially those that self-prune their dead lower branches are often unharmed as they typically do not facilitate crown fires. Overall, in situations where trees are not completely scorched, tree morphology combined with seasonality generally influences fire effects on the aboveground portions of a tree.

When describing stem effects, bark thickness typically has the greatest influence on how a fire impacts a tree stem. Bark thickness is generally species specific, and dependant on various factors including tree diameter and age as well as distance above the ground, site characteristics, and tree health and vigour. The amount of influence that bark thickness has on stem fire effects can be understood from the following example. When charring occurs on the stem of a thick-barked tree (Douglas-fir, ponderosa pine), it does not necessarily mean that the cambium is extensively damaged, in fact, it often only corresponds to a fire scar. Fire scars are typically caused by an uneven distribution of heat that often occurs on the upslope and/or lee side of a tree. However, when the stems of thin-barked trees, including lodgepole pine, subalpine fir, aspen, or spruce are charred it generally corresponds to tree death. Typically, the survival of thin-barked trees is related to flame length, flaming residence time, and stem char height with most of these trees only surviving patchy fires which fail to damage the cambium throughout its circumference. As stated above, thicker barked trees, such as large Douglas-fir, western larch, and ponderosa pine can often sustain a substantial amount of bark char before cambium damage occurs. Moreover, older, thick-barked trees are often only damaged or killed when the cambium is subjected to complete girdling or when the trees are subjected to subsequent fires. This generally only happens when these trees are subjected to long duration burns such as those that occur during the burnout of logs, deep litter, and duff (smouldering ground fires). Most stands however, due to their low fuel loads, often cannot sustain a fire of this magnitude and thus cannot facilitate the complete girdling of a tree. Overall, thick bark increases tolerance to most ground fires, even those that burn into the bark. The deeper the fire burns however, the more likely complete girdling is to occur. Thus, thick-barked trees are more likely to succumb to fire from crown damage than stem damage.

POST-FIRE SPROUTING

In general, the physiological processes controlling post-fire sprouting is similar for all plants including trees, shrubs, forbs, and grasses. The ability of an individual plant to sprout following a fire is dependant on the location of its dormant buds, the subsurface distribution of reproductive structures, and the depths below the surface from which new shoots can develop. These morphological characteristics, combined with fire severity, typically determine the number of growing points (reproductive buds or bud primordia) that are able to survive a fire. That is, the relationship between the depths of reproduction organs, combined with the depth of lethal temperature penetration, will determine a plants ability to survive and sprout following a fire. For example, high-severity burns were described as having the potential to retard or reduce suckering, especially when the shallow roots were exposed to lethal heating. In general, many common shrubs and trees are able to sprout from surviving plant parts following a fire. Re-sprouting typically occurs when their buds are protected by bark, dense leaf bases, or soil. This includes buds that are located on belowground masses of woody tissue, including lignotubers, burls, root crowns (e.g., alder, willow, saskatoon), as well as on rhizomes (e.g., snowberry, *Vaccinium* spp.), stolons (e.g., silverberry) and within tissues of stems (e.g., antelope bitterbrush, bigleaf maple, rabbitbrush, and paper birch) either above or below the surface. In order for other, more vulnerable, non-sprouting species such as most coniferous trees (Douglas fir, lodgepole pine, spruce, ponderosa pine) and big sagebrush, to re-establish or colonize, they must originate from off-site areas that were unaffected by fire.

Whether or not lethal temperatures occur is dependant on numerous factors including growth form, fuel loading, adjacent vegetation and fuel and foliar moisture levels. Fuel loading, as well as heat from adjacent vegetation (forbs, shrubs, and trees), can dry and preheat trees to ignition temperature. This can increase tree mortality, especially when compared to similar sites, burned under similar conditions, with lighter fuels loads and/or sites with fewer trees and shrubs. If however, plants are actively growing, or if a site is relatively moist, foliar and fuel moisture levels may prevent fire from entering a stand of plants. Other indirect impacts can also influence survival and sprouting following a fire. For example, increased erosion may result in pedestalling around individual plants thus exposing previously protected plant parts to either predation or increasing the possibility of drought stress on these plants, both of which can reduce vigour, limit sprouting, or even cause death. In addition, long-term fire intervals generally increase fuel accumulation and fire severity whereas short-term fire intervals can influence community composition by decreasing seeding establishment. Changes in fire return intervals may impact individual species or communities that are adapted to specific return-intervals.

Factors such as tree age can also determine sprouting ability. For example, decreased amounts of post-fire sprouting observed in older aspen stands was hypothesized as being attributed to the deterioration of the roots to a point that prohibited re-sprouting. Also, depending on species, younger plants that have developed from seed may not be able to sprout until they have reached a certain age. Exactly when re-sprouting occurs is dependant on seasonality and fire severity. If fire occurs early in the growing season and soil moisture is or becomes available, plants may sprout soon after a fire. If the fire occurs after dormancy occurs, sprouting will not occur until the following spring.

Depending on season, increases in soil temperature and nutrient availability associated with fires may also enhance sprouting. Whether sprouting actually occurs however, is determined by the availability of nutrients and carbohydrates in the regenerating structures or adjacent roots. If sufficient amounts of energy are not available to support new growth, until it is able to become photosynthetically self-sufficient, sprouting will generally not occur. Overall, fire tolerant species, such as Douglas fir and ponderosa pine, as well as species that are able to re-sprout (snowberry, aspen) or develop quickly from seed (lodgepole pine), tend to become important components of the post-fire community.

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