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A STRATEGY FOR PRESCRIBED BURNING BIGHORN SHEEP RANGE IN WINTER

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Abstract: The seasonal variation in the heat and moisture content of live tree foliage suggests a possible strategy for safely prescribing stand-replacing fires during the winter for establishing or maintaining high elevation sheep range. We discuss the possible burning prescriptions and ignition techniques that will produce crown fires in a mature forest stand without significantly reducing the organic soil profiles or adversely affecting the understory plant cover. The logistical, ecological and economic ramifications of our proposed strategy are also discussed.

Bighorn sheep (Ovis canadensis canadensis) range in Alberta can be described as semi-open to open alpine or subalpine plant communities adjacent to rugged escape terrain (Stelfox 1976, Bentz and Woodard 1988). Although this sheep species is known to use a variety of seasonal home ranges throughout the year (Geist 1971), most areas are dominated by graminoids forbs and short shrubs. Stelfox (1976) found that forbs and shrubs were nearly as important as grasses in fulfilling the year-round diet requirements of sheep. Perhaps more importantly, sheep remain almost exclusively on grasslands and rocky escarpments because of an apparent need for openness in close proximity to escape terrain (Risenhoover and Bailey 1985, Bentz and Woodard 1988).

Fires, prescribed or natural, induce habitats that are heavily used by bighorn sheep (Bentz and Woodard 1988). Stelfox (1976) pointed out that fires not only create new grasslands but periodically redistribute the biomass between groups of plant species by changing the environmental conditions on these disturbed sites. It has been suggested that burning may enhance the production, availability, and palatability of important forage species (Peek et al. 1979, Hobbs and Spewart 1984). Others have argued that periodic burning keeps seral grasslands from becoming dominated by climax coniferous tree cover (Geist 1971, Stelfox 1971, 1976). Some recent research has shown that on burned sites sheep use areas more distant to escape terrain than on adjacent unburned sites (Shannon et al. 1975, Bentz and Woodard 1988). These two studies concluded that this increase in use-distance is due to increased visibility. Recent work by Bentz (1981), Michalsky (1987), and Bentz and Woodard (1988) demonstrated this increase in use-distance is not related to differences in plant community composition or structure between burned and adjacent unburned areas. Regardless of the reasons for increased sheep use on burned areas adjacent to escape terrain, there is ample evidence to recommend the use of fire as a cultural tool to maintain or increase bighorn sheep range in Alberta or elsewhere (Thomas 1984).

Few adverse effects of burning on sheep or sheep range have been documented. Spowart and Hobbs (1985) "recommend that burns be large enough to prevent interspecific competition between ungulate species for available forage and that burn areas should be interspersed with adjacent unburned site to allow maximum nutritional alternatives to sympatric ungulate populations". Another report (Woodard et al. 1983) suggested that natural or prescribed fires burning under extremely dry conditions could have significant adverse impacts on soil profile. These impacts may occur as a direct result of burning, through the combustion of the organic profile, or as a result of soil erosion caused by heavy precipitation or extreme wind following burning. Most soil profiles at high elevation consist mainly of organic material, which will burn when dry. In the absence of complete combustion, the removal of the overstory canopy, and for a short-period the understory plant cover, may make soils on these steep slopes highly susceptible to wind and water erosion. Therefore, wildfires should be suppressed when they threaten these stands during dry conditions, and prescribed burning should be avoided when such conditions exist.

Little is known about fire behavior and the historical weather patterns for specific alpine sites. A shortage of high-elevation weather stations for documenting the micro-weather variations for the various aspects, elevations, physiographic changes and topographic variations makes it difficult for managers to predict how fires will behave under different fuel conditions. Most existing fire behavior models have not been validated for these sites. Also, most land managers do not have a wealth of practical experience in dealing with alpine and subalpine fires in this province. These factors tend to increase the risk of prescribed burning these high elevation sites, and this increased risk or uncertainty generally results in increasing costs. The amount of burning accomplished is often restricted due to the increase in costs associated with insuring prescribed fires are controllable, yet fulfill well defined objectives. The goal of this paper is to describe a burning prescription, which was developed from theory, that will allow managers to safely and cheaply prescribe a stand-replacing crown fire on a bighorn sheep range that has been overtaken by mature coniferous tree cover. The prescription attempts to minimize the effects of burning on the soil profile.

The Strategy

Historically, attempts at prescribing stand-replacing fires have been developed from identifying or describing fuel, weather, and topographic features that in combination with ignition procedures will enable a surface fire to develop into a self-perpetuating crown fire (Van Wagner 1977, Martin and Dell 1978). Generally, ground and surface fuels are allowed to dry to such an extent that when ignited under extreme conditions of wind (>20km/hr), slope (>30%), temperature (>15^{0}C), and relative humidity (<25%), fires spread rapidly. Under these conditions, flame lengths due to rapid reaction rates (fireline intensity (I_B), Byram 1959, Alexander 1982) are high; thus maximizing the probability that crowning will be sustained. Also, under these conditions, surface burning dries aerial fuels and when ladder fuels are present or when the fireline intensity is high enough, crowning will occur. Unfortunately, these types of fires usually consume the organic layers of the soil profile.

The result is a significant reduction in growth productivity of a site due to the loss in available growing media.

The goal of our strategy is to prescribe a self-sustaining crown fire which will burn in the absence of surface burning. There are no documented reports of sustained crowning occurring in the absence of surface burning but it is theoretically possible (Thomas 1967, Frandsen 1971, Van Wagner 1977). We suspect the absence of documented evidence is most likely due to the fact that when sustained independent crowning does occur, conditions are so dangerous that personnel are not close enough to observe its occurrence. Results from Van Wagner (1963) showed that moisture content significantly affects the probability of sustained burning. Christmas trees at less than 20% moisture content by oven-dry weight burned "with great violence when ignited by a match. Those at 50% moisture content burned readily, while trees over 100% could not be ignited using a point source of heat. Although these results and those of Quintilio (1977) might not pertain to the type of fire we are prescribing, they do represent the only data remotely applicable.

The conditions required for an independent crown fire have been described (Van Wagner 1977). In general, it is assumed that fuel moisture contents must be low, crown fuels must be continuous and have a low to moderate bulk density, energy levels must be normal to high, and the wind and slope components, which can significantly affect fire behavior must be extreme, >35 km/hr and >45%, respectively. Although there is a shortage of good fuel moisture and heat content data for coniferous tree species at this elevation, work by Fuglem and Murphy (1980) does suggest moisture contents may be low enough to produce desired conditions (Figure 1).

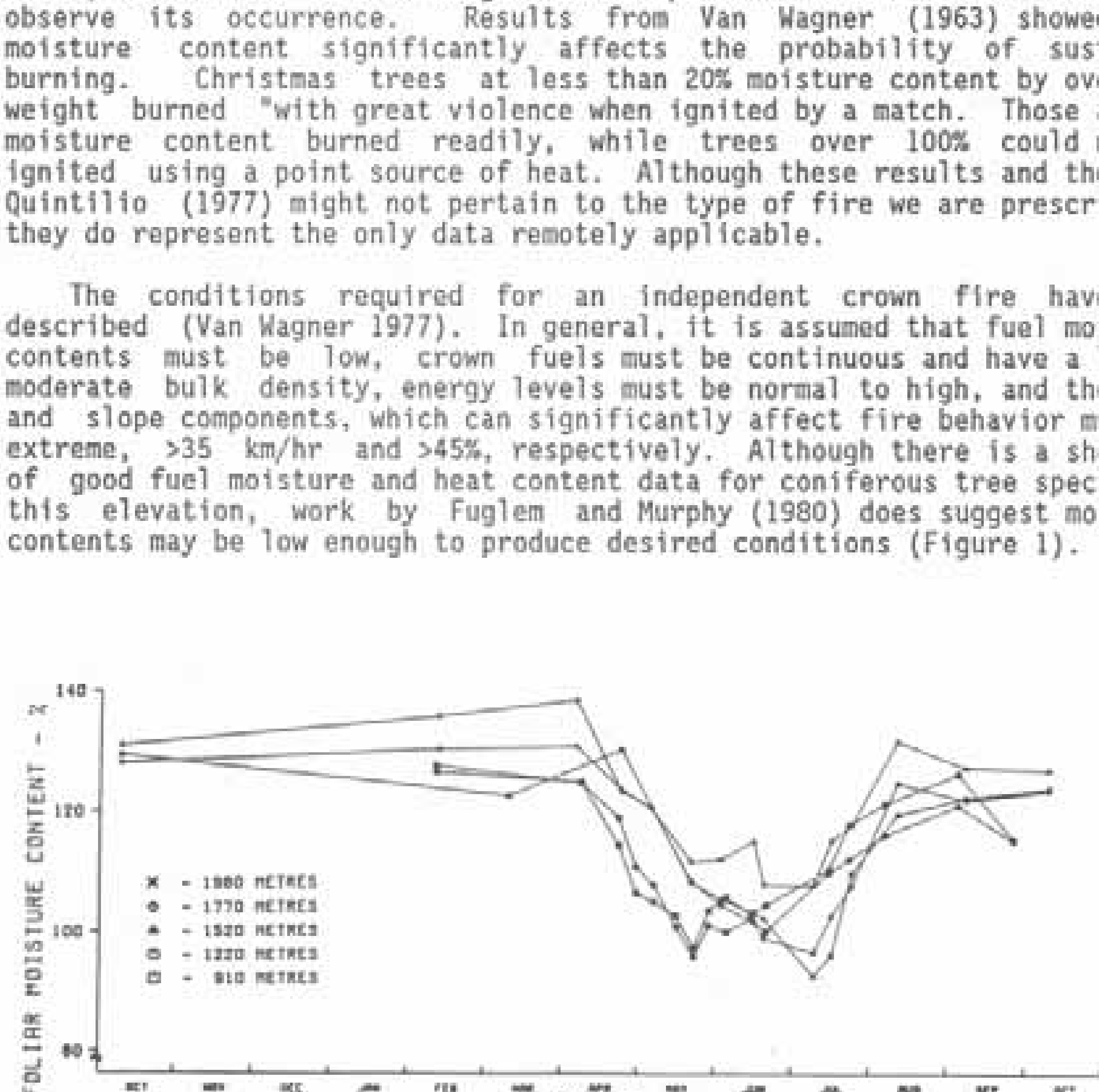

Figure 1. Foliar moisture content (dry weight moisture percent) of lodgepole pine at foothills sampling locations (each plotted value is the mean of six observations) (extracted from Fuglem and Murphy (1980); p. 15).

Results from their work, although limited by sampling intensity within and among years, and species type does clearly show the magnitude in foliar moisture content levels to be expected throughout the winter months for lodgepole pine at various elevations. These trends in moisture levels are consistent with other published work for other plant species (Russell and Turner 1975, Chrosciewicz 1986b). Although, the winter moisture contents reported by Fuglem and Murphy (1980) are considerably higher than those considered necessary for sustained burning (Van Wagner 1963), it is still possible that winter burning could be operationally feasible. We believe the sampling frequency in Fuglem and Murphy (1980) was not sufficient to detect significant moisture changes. It has been well documented that Chinook winds in combination with the higher ambient air temperatures commonly associated with them can dry live aerial fuels. In fact, if severe enough or sufficiently persistent, these winds can sufficiently dehydrate individual trees to the point that complete stands of conifers on the east side of the Rockies are killed; a condition known as "Red belt" in Alberta (Bella and Navratil 1987). Therefore, it seems logical to conclude that foliar moisture contents could be low enough to sustain an independent crown fire.

Data on the seasonal trends in foliar heat content in conifers also suggest winter burning may be possible (Little 1970, Philpot and Mutch 1971). Chrosciewicz (1986a) shows that the average high heat content of old white spruce foliage fluctuates from 20,400 kJ/kg in late May to 20,800 kJ/kg in mid-July back down to 20,300 kJ/kg by early September. Unfortunately, because of the limited time span in his data set it is impossible to determine what the heat content is during the winter months, although, it would seem highly unlikely that they would be much below the early September or late May values for old foliage. We expect very little energy in the form of extractives, tannins, oleoresins and carbohydrates are being added or removed from the live old foliage during the winter months because the cold temperatures and the frozen soil prevents very little biological activity from occurring in the tree. Further, we speculate the proportion of flammable biomass to water is increasing due to transpiration losses and the inability of the tree to translocate water from frozen soil, because although transpiration losses are minor during the winter period, there are losses due to respiration and even cooling if trees are subjected to warm, dry winds. But even if we are wrong, high heat contents of even 20,300 kJ/kg are significantly higher than 19,000 kJ/kg which is widely accepted as the average high heat content of most woody fuels (Byram 1959, Alexander 1982).

We speculate tree foliage will support crown fires at this elevation if the tree canopies are ignited from above under conditions of high winds (20-25 km/hr) or steep slopes (>45 %). The aerial drip torch or helitorch, which uses "SUREFIRE" (Fireflex Manufacturing's trade name for Calford G.; Lafferty 1984) or "PETRO GEL" (produced by Circle Park Holdings) appears to be the ignition system most suited to winter burning. Other aerial ignition systems such as the Aerial Ignition Device (AID; Lait and Muraro 1979) or the other types of fuses (Jukkala 1984) are not recommended because: (1) they will not adhere to the tree canopy like gelled gas, (2) they do not have the residence time of gelled gas, and (3) they can not produce flame temperatures equal to gelled gas (Brown 1984). These three factors must be considered when burning a porous and potentially moist fuelbed.

Even the wettest fuels will burn if enough heat is applied to dry the fuel below the moisture content of extinction level (Van Wagner 1963). High wind and steep slopes will increase reaction rates (I_B) thus increasing the probability of fire spread between tree crowns (Rothermel 1983, Alexander 1985). Woodard et al. (1983) reported on the value of this ignition technique during a spring fire which crowned under no wind; yet slope steepness varied from 25 to 55%. Their results showed that crowning could be induced with the use of the helitorch even though surface burning could not be sustained when surface fuels were strip-head fired (Martin and Dell 1978) with hand-held drip torches.

Historically, the use of the helitorch fuel was restricted by minimum ambient air temperatures required for fuels to gel. Temperatures below 15^{o}C greatly increase time required for a thorough setting of the "ALUMNI-GEL" and gas mixture. A peptizer was required when mixing this fuel between -25^{o}C and 15^{o}C. But even with a peptizer, which is an extremely toxic substance and thus dangerous to handle, gelling may take as long as 18 hours to achieve good consistency. This gelling time severely restricts the value of this product when temperatures are low. Current advances in the chemistry controlling the gelling now allows firing teams to achieve reliable product and results under any temperature condition >-25^{o} C if "SUREFIRE" or "PETRO-GEL" are used. Therefore, it seems reasonable to accept the premise that the energy levels needed to initiate combustion are available, and these chemicals and delivery systems are reliable for winter burning.

OTHER CONSIDERATIONS

Chinook winds occur frequently in Alberta and the effects of these warm, downslope winds should be considered when developing burning prescriptions. Burning should not be attempted during the Chinook condition. Flying aircraft in mountainous terrain is extremely dangerous during chinooks. Therefore, we do not recommend burning or even flying when wind speeds exceed 25 km/hr. Gradient winds should also be accounted for when determining the location and timing of ignition. The strength and direction of these winds will significantly affect the direction and rate of fire spread as well as the probability of long range spotting. We recommend prescribing burns when surface upslope winds are the strongest during the burning period. Strong upslope winds in combination with steep slopes will greatly enhance the establishment and maintenance of independent crowning. Upslope winds also permit helicopter flying when winds are even a little stronger (perhaps up to 30 km/hr). Also, fuel-free mountain tops or ridges will provide natural fuelbreaks. The adoption of this strategy will enable wildland managers to better control the downslope perimeter of the disturbed area. There seems to be little need to burn areas >300 m from escape terrain (Oldemeyer et al. 1971, Bentz and Woodard 1988). Spotting is unlikely if burning occurs when the forest floor is frozen in the burned site. It is not uncommon for south and southwest slopes to go snow-free as a result of solar radiation and Chinook winds while other aspects are still snow covered. Hence, we believe the probability of fires escaping the target area is extremely low even if large firebrands (>2 cm in dia.) are carried aloft. As a result, very few if any firefighters would be required to contain the fires we are proposing here.

COSTS

Costs of prescribed burning varies among individual burns based on the size of the area to be burned and the desired results. These two factors directly affect: (1) the amount of labour and equipment required to construct needed fireguards, (2) the size of suppression or control forces, (3) the number of helicopters required, (4) the size of the overhead and mixing teams, and (5) the amount of mop-up or surveillance time required. With our strategy, all of the above costs are significantly reduced. In addition, the number of "false starts" (when prescribed fires are cancelled because of failures to satisfy burning prescriptions but usually after firefighters and equipment have been located, moved or diverted) are reduced. "False starts" significantly contribute to the costs of prescribed burning. We also anticipate that it will be easier to predict prescribed weather conditions, because of the broader burning prescriptions (Brown 1984). Yet, we anticipate winter burning costs may be a little higher at first due to a lack of experience in forecasting weather at this elevation and for this period. Fire weather forecasters have not paid much attention to the weather at these elevations during this season. Therefore, we anticipate the number of "false starts" in accomplishing winter burns will drop off significantly after we have gained a little experience.

ECOLOGICAL EFFECTS

Vegetation

Winter burning of coniferous stands of trees is not a common practice in Alberta or elsewhere. Therefore, we as managers or scientists lack the information necessary to determine what effect this type of stand disturbance will have on the understory plant community. We expect our prescription will not significantly reduce the preburn cover and composition of the grasses, herbs and short shrubs if burning occurs when the litter fuels and duff are frozen. This prescription objective will maximize the probability that these plants will be killed or severely disturbed as a direct result of burning or exposure to thermal radiation; thus giving the competitive advantage to the more desired grasses and herbs.

Perhaps the major limitations of this prescription is that it will not reduce organic soil layers, or if heat is needed to break the seed dormancy of preferred plant species; this will not occur. In our opinion, if either of these two objectives are desired then a subsequent spring burn could be more safely and cheaply executed in the absence of the overstory canopy cover. Burning during early spring conditions with snow in the adjacent unburned stand would reduce the need for expensive fire-guarding. The burned area would most likely go snow free earlier, due to removal of the overstory tree canopy cover, and the fire could be more easily contained to the treatment area.

Sheep

Winter conditions can severely stress individual sheep or even a whole population of sheep in a specific area. Managers are usually careful not to impose additional stresses at this time of year because of the likely increase in average mortality levels. The presence of helicopters and people on or near occupied winter range may add to the stress experienced by the sheep. Depending on the condition of individuals in the herd this additional stress may prove fatal. Therefore, herd condition should be considered when timing burns. Early spring burns, particularly on south and southwest aspects, may provide more early spring forage than would otherwise be available. Thus, even if burning activities do increase stress levels in a population the earlier "green-up" of plants may compensate for any adverse impacts. In some areas, where the available sheep range is quite large and affords alternate and distance wintering sites, burns may be prescribed or located to minimize the stress on sheep.

SUMMARY AND CONCLUSIONS

Prescribing crown fires in mature, coniferous stands adjacent to escape terrain during the winter months may provide an inexpensive, yet effective, solution to maintaining or establishing Rocky Mountain bighorn sheep winter range. The prescription strategy presented relies on surface fuels being frozen, high upslope winds, steep slopes, uniform and continuous tree cover, and a helitorch ignition system, which uses some type of gel-gas mixture. We anticipate no control problems and all other costs associated with prescribed burning should be minimized with this strategy. Based on current fire behavior knowledge our prescription is extremely safe because it is extremely conservative. We believe qualified fire behavior officers may feel comfortable burning without snow on other aspects, particularly if the soil and ground are still frozen.

If our strategy fails, it will be because the trees will not sustain crowning independent of surface burning. We do not interpret this to be a problem. The deposition of flammable gel on live trees will kill plant tissue. Depending on the amount of live tissue killed in each individual tree, whole stands of trees may be killed without the need for wide-spread crowning. Our goal is not to prescribe a catastrophic "BONFIRE" but rather to open up the stand by killing the overstory tree cover.

Managers may find ignition costs prohibitive if large amounts of gelled-gas and helicopter time are required to kill stands that will not support crowning. But these costs will have to be very high to off-set the expense of not getting the job done because helicopters and firefighters were not available when burning is possible or when faced with paying for suppression crews to control prescribed burns and we have not even discussed the costs of "false starts". We conclude by saying "our strategy may not work, BUT in our opinion it is worth a try because from our experience with prescribed burning, the costs and possible losses are negligible compared to other alternatives".

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