INTRODUCTION
Early in the spring of 1808, David Thompson and his men canoed down the Kootenay River in what is now southeastern British Columbia. They camped for a few days in a grassy area called Tobacco Plains, close to the Montana border. Thompson, ever the observer, scanned the area with his telescope and noted how far the grassy openings extended up into the forests on either side of the valley. He also discovered a remarkable larch tree, and took the time to measure it. The larch towered 150 feet from the ground to the first branches, and measured 13 feet in diameter.

Since David Thompson’s time, these fire-maintained forest types have been severely damaged, through a combination of early “highgrade” logging and indiscriminate slash burning, followed by modern fire suppression. This bulletin explores the basics of fire-maintained ecosystems, the impact of forest ingrowth, and the potential solutions.

THE ROLE OF DISTURBANCE IN FORESTS
Natural disturbance regimes are central to the life of any forest, and ecologists have found that forest ecosystems can be classified by the frequency and severity of the most dramatic of all natural disturbances—fire. Paradoxically, as fires become less frequent, their impact becomes greater. The wet coastal forest zones of British Columbia are classed as “ecosystems with rare, stand-initiating fires” (Ministry of Forests, 1995): in other words, fires occur so infrequently that when they do, the large amount of fuel accumulation usually means that the stand is destroyed and the forest starts over. In drier forests, fires start more easily, fire-intolerant species are eliminated, and fuels are consumed periodically instead of building up. These types are “ecosystems with frequent, stand-maintaining fires,” or, more simply, “fire-maintained ecosystems.” (They are also referred to as Natural Disturbance Type 4 or NDT4 ecosystems).

DISTRIBUTION OF FIRE-MAINTAINED FORESTS
The locations of fire-maintained forests generally follows the distribution of the Interior Douglas-fir (IDF), Ponderosa Pine (PP), and the forested parts of the Bunchgrass (BG) Biogeoclimatic zones. These zones are generally found below 1300 meters in the drier valleys of B.C.’s southern Interior, such as the Fraser, Chilcotin, Kootenay, Columbia, Thompson, Okanagan, Nicola, and Kettle river systems. Substantial areas of IDF not associated with valley systems are found in the Cariboo-Chilcotin Plateau.
FIRE PERIODICITY
In determining the long-term fire history of a forest stand, a key piece of information is fire periodicity, or the long-term average rate of fire entry in the stand. Periodicity is determined primarily by tree-ring analysis of fire-scarred trees. When a fire burns through the bark of a tree but does not kill it, a fire scar is created, and every subsequent fire then leaves its mark on the scar. Using dendrochronology techniques, an average fire periodicity can be determined from these fire-scarred trees.

There is a growing body of British Columbia fire histories based on dendrochronology records. Here are a few examples:
• Grasmere, mixed ponderosa pine/Douglas-fir stand: fire every 6.4 years between 1813 and 1940 (Dorey, 1979)
• Castlegar, seral ponderosa pine stand: fire every 11.6 years between 1762 and 1937 (Beck, 1984)
• Canal Flats, single larch veteran: fire every 26 years, between 1589 and 1937 (Stewart, pers. comm)
• Chilco tain region, open-grown Douglas-fir/grassland type: fire every 9.8 years between 1759 and 1926 (Parminter, 1978)

Fire occurrences after about 1900 are confounded by wildfires started by European mining, logging, settlement and railway activity, which culminated during the drought of the 1930's with many large, damaging fires. Then, beginning about 1940, organized fire suppression became effective. Thus the determination of the natural fire periodicity and forest structure is ideally based on data from prior to 1900.

FIRE ADAPTATION
When flora and fauna are subject to a natural disturbance regime for hundreds or thousands of years, they adapt to that disturbance. The set of flora and fauna that thrive in areas of high fire periodicity are called fire adapted. Fire adaptation can be passive, as in the thick, fireproof bark of a ponderosa pine, or active, as in the cones of lodgepole pine, which will not open to release their seed until they have been heated by fire.

The aboriginal influence on fire periodicity poses an interesting question. There is ample evidence of the aboriginal use of fire in the ecosystem; David Thompson, among other early observers, made note of the practice. Comparisons of historical fire-scarring with modern data on lightning-caused fires suggest pre-contact fire regimes were too frequent for lightning to be the sole source of ignition (Kay, 1994). Aboriginal burning was done to improve hunting conditions, to enhance usefulness of certain types of vegetation, to lessen the chances of surprise attack, and for many other reasons we are not yet aware of (MacCleery, 1994). If this aboriginal practice persisted for hundreds or thousands of years, we may assume that it too became part of the natural disturbance regime to which plants and animals have adapted.

THE RELATIONSHIP OF TREE SPECIES TO FIRE
Tree species have very different responses to fire. Ponderosa pine and western larch are thick-barked, sun-loving species that often dominate the canopy in a fire-maintained forest. Douglas-fir is a thin-barked, shade-tolerant tree that is the primary agent of ingrowth in fire-excluded stands. Seedlings and saplings of Douglas-fir are easily fire-killed, but mature trees of the species do develop thick bark and can become quite fire-tolerant. Because natural fire patterns are always patchy, a percentage of Douglas-firs will survive and form part of the fire-adapted forest canopy, along with pine and larch. Spruce, hemlock, cedar and aspen have little fire tolerance, although aspen roots sucker extensively, producing new seedlings after fire.

Lodgepole pine has a complex fire response. Individual lodgepole trees, whether juvenile or mature, are very flammable, but the species is well adapted to establish after a hot fire. Many of the lodgepole stands seen in the British Columbia Interior originated right after hot, stand-destroying fires, producing the characteristic, even-aged lodgepole monoculture. Once these stands mature at 80 to 120 years, they are subject to insect and disease invasions, blowdowns, and subsequent hot fires. When these stands do burn, the stand replacement cycle starts all over again.

Additional information on fire periodicity and stand structure is derived from early accounts and from archival photographs. Fire incidence and vegetation types in the distant past can be inferred from ash and pollen sediments in lakes. Sediment cores in the lakes of the East Kootenay Trench show long periods of abundant sagebrush pollen, which indicates the presence of dry, grassland-type vegetation. (Hebda, 1995).
WHAT DOES A HEALTHY FIRE-MAINTAINED FOREST LOOK LIKE?
Wide-open, parklike stands of widely-spaced pines, larches and firs. Density ranges from a few dozen to a few hundred stems per hectare. Trees of all age-classes are present, but there is a prominent overstory of mature and old-growth specimens. These veterans have lost their lower branches, and their thick bark makes them nearly fireproof. Because the trees are widely spaced and growing vigorously, there is little opportunity for disease or insect outbreak. The open forest canopy lets in lots of sunlight, so there is abundant grass and shrub growth at ground level. When a fire starts, dry grass allows it to carry along the ground, but there is not enough fuel to carry the flames up into the tree canopy. A few tree seedlings and saplings are killed, and the fire is over in a few hours. Burned grasses and shrubs survive, to resprout next spring.

WHAT HAPPENS WHEN NATURAL GROUND FIRES ARE SUPPRESSED?
When the natural thinning action of periodic surface fires is stopped, a whole new “understory” of tree seedlings quickly establishes underneath the existing forest. Where the original stand is typically a mixture of ponderosa pine, larch and Douglas-fir, the new understory will be predominantly Douglas-fir. If allowed to continue, the stand will eventually become populated with more trees than the site can support; this is the process we call ingrowth. Stem density can exceed 10,000 per hectare. A parallel process favored by fire suppression is encroachment, the establishment of new tree seedlings on open grassland sites.

WHAT ARE THE EFFECTS OF FIRE IN FIRE-MAINTAINED STANDS?
The primary benefit of surface fires in fire-maintained stands is the thinning process, which keeps tree stocking at a level that the site can support. Fuel management is another benefit: frequent fires prevent dry fuels (dead branches, needles, dead grass etc.) from accumulating to levels that lead to hot, destructive fires. Some nutrient recycling may occur, through the release of nitrogen, phosphorous, and other nutrients that would otherwise remain locked up in woody materials. Surface fires can also stimulate regeneration of trees and ground cover, by releasing serotinous seeds and exposing patches of mineral soil, facilitating seed germination. The temporary darkening of the soil surface with ash and the reduction of the insulating duff layer also means that springtime soil temperatures are higher, resulting in earlier plant growth. Since the ground fires tend to be small and random over time and space, the healthy fire-maintained forest becomes a very diverse mosaic of age-classes and structures.

INGROWTH EFFECTS ON FORAGE AND BROWSE PRODUCTION
The fire-maintained grasslands and open forests of the Bunchgrass, Ponderosa Pine and Douglas-fir zones have historically produced large quantities of good quality forage and browse. These areas are prime winter range for deer, elk and sheep, as well as critical spring/fall range for livestock. There is an inverse relationship between understory forage production and the density of the forest canopy; as canopy closure increases through forest ingrowth, forage and browse production decreases (Dodd et al, 1972). There is also a loss of forage quality: the native bunchgrasses associated with fire-maintained stands produce high protein levels during the growing season. This protein, a critical part of the grazing animal’s diet, remains fixed in the upright bunchgrasses, so it is available to wild ungulates through the winter. In closed and ingrown stands, the lower-growing pinegrass predominates. It produces lower protein levels in the summer and does not retain its protein through the winter.
INGROWTH EFFECTS ON FOREST HEALTH
In fire-maintained ecosystems, fire and forest pests are inextricably linked: if ingrowth proceeds long enough, forest pest outbreaks are inevitable. Once the outbreak does occur, the increased fuel loading from dead and dying trees means that catastrophic fire eventually follows. As a stand ingrows, intertree competition for light, water and nutrients becomes very intense, and growth slows down. In this stressed condition, trees become more susceptible to attacks by bark beetles, defoliating insects, mistletoe and fungi. Increased tree density means there is a greater likelihood of intertree contact through root systems, thus facilitating the spread of root diseases such as Armillaria. The stressed condition of crowded trees can also make them more prone to damage from drought or snow breakage.

INGROWTH AND WILDFIRE
From a fire-protection perspective, increased fuel loading is the most obvious result of forest ingrowth. The understory of dense, flammable juvenile trees means that fuels are more continuous across the landscape, but these juveniles also provide vertical fuel continuity as well. In other words, a dense understory of seedlings and pole-sized trees can provide the ladder fuels that will allow a ground fire to escape upward and become a much more damaging crown fire. The suppression of fire in fire-maintained ecosystems certainly provided some initial gains in timber values and public safety, but the increased risk of catastrophic fires is now beginning to outweigh those gains. This becomes particularly important as urban and suburban settlement increases along British Columbia's dry interior valley corridors.

INGROWTH AND WILDLIFE
As previously mentioned, the loss of forage and browse impacts wild ungulates, but many other wild animal species are affected as well, such as birds, small mammals and reptiles (Kremsater et al., 1994). Prominent B.C. species put at risk by forest ingrowth are the horned lark, vesper sparrow, long-billed curlew, Columbian sharp-tailed grouse, and the yellow badger (Gayton et al., 1995).

WHAT CAN BE DONE ABOUT FOREST INGROWTH?
Carefully planned prescribed burns, together with a selective "let burn" policy, where naturally-occurring wildfires in selected areas are allowed to take their natural course, are two obvious methods of controlling ingrowth. But the reality of today's fire-maintained forests is that they contain valuable timber, are often close to settlement, and their fuel loadings can be dangerously high. These factors mitigate against the use of prescribed burns as the primary treatment. Recent operational trials have shown that commercial and pre-commercial thinning can substitute, to some degree, for fire. Once the thinning has been done and the fuels have dried out, the stand can be scheduled for prescribed burns that are appropriate to its natural fire history. From a timber perspective, thinning can provide some short-term wood (both for sawlogs and pulp) while preparing the stand for modest timber gains over the long term. Much work is yet to be done, but a general pattern of fire-maintained ecosystem restoration is emerging, that will involve combinations of thinning and prescribed burning. The results will be improved forage, timber and environmental values, within the context of a sustainable ecosystem.

ECOSYSTEM MANAGEMENT AND FIRE
The restoration of fire-maintained ecosystems is part of a larger initiative known as ecosystem management, that attempts to recognize the biological limits of natural resources, and to manage them through natural processes whenever possible. We will never go back to the forest conditions of David Thompson's time, but a knowledge of those historical conditions helps us to manage appropriately into the future.

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