Federation of Alberta Naturalists

8. Old-Growth

Old-growth forests are unique in terms of their structure and ecological processes. Consequently, the maintenance of old growth is critical to the maintenance of forest biodiversity. In this chapter I review the status of old-growth in Alberta, including a discussion of dynamics (origin and loss) and an assessment of current quantity and distribution. In the concluding section I discuss management options for maintaining old-growth and the biodiversity associated with it.

The focus of this chapter is on the management of old-growth forests occurring within the industrial land base. Black spruce and larch, which are generally not targeted for harvesting in Alberta, are not included in the analysis or discussion.

General Ecology of Old-Growth

Defining Characteristics

The unifying feature of old-growth is not age per se, but the set of characteristics shared by most forest types in the later stages of succession. A key feature is breakup of the canopy due to the mortality of individual trees as they reach maturity (Burton et al.,1999). This process in turn leads to the release of understory plants, accumulation of snags and downed logs, and in some cases, the emergence of secondary canopy species (Stelfox, 1995: *v*). Relative to younger stages, old stands have trees of many ages and sizes and have more large canopy trees, large snags, and large downed logs (Burton et al., 1999; Lee et al., 2000). Overall, structural diversity is highest in old stands, and this is reflected in unique plant and animal communities as well as high overall species richness, relative to younger stands (Stelfox, 1995: *vi*; Timoney, 2001).

A Working Definition

Although it would be preferable to identify old-growth stands directly on the basis of the previously described structural criteria, timber inventories do not contain the required attributes. An alternative approach is to develop simple working definitions of old-growth based on known relationships between stand age and successional stage. Age-based definitions of old-growth must be defined separately for each stand type because tree species mature at different rates (Table 8.1). Also, it should be understood that age-based definitions provide only a coarse assessment of old-growth (Lee et al., 2000). There is substantial variability in the rate of stand development due to local variations in soil and climate, among other factors, and timber inventories are known to systematically underestimate the age of older stands (Cumming et al., 2000).

Table 8.1. Typical age at which old-growth characteristics are apparent, for commercial forest stand types in Alberta.

Forest Type	Old-Growth Age[1]
Deciduous	> 100
White spruce	> 140
Mixedwood[2]	> 100
Pine	> 120

[1] Adapted from Timoney, 2001.
[2] Mixture of coniferous and deciduous species.

Ecological Importance

Old-growth stands contribute to the maintenance of forest biodiversity in several ways. For some species, advanced tree age is itself a critical attribute. For example, plant species that require a long time for colonization and growth, such as lichens, are often found only in abundance in old-growth stands (Esseen et al., 1996). Cone-eating birds, such as the red crossbill, are dependent on the existence of old-growth because older coniferous trees produce many more cones much more consistently, and of greater size, than do younger trees (Benkman, 1993). Many species, including little brown bats and pileated woodpeckers, seek out the large old trees found in old-growth stands for foraging and roosting (Crampton and Barclay, 1998; McClelland and McClelland, 1999). Finally, the accumulation of large dead wood, characteristic of old-growth stands, supports unique assemblages of wood-decomposing species (Crites and Dale, 1995), as well as providing foraging opportunities and shelter for many other species (Lee et al., 1997).

In more general terms, the complex structure of old-growth provides a large variety of habitat types for exploitation by species with specialized requirements. Consequently, old-growth stands have the highest overall diversity of species, relative to other age classes, with representation of many rare species (Stelfox, 1995: *vi*). Furthermore, many species have their greatest abundance in old-growth. For example, Schieck and Nietfeld (1995) found that 21 of the 33 bird species they studied in the boreal mixedwood forest had their highest abundance in old-growth stands, and nine of those species were more than four times as abundant in old stands as in other ages. A number of bird species, such as the black-throated green warbler, brown creeper, and goldencrowned kinglet are essentially restricted to old-growth stands (Kirk et al., 1996). Similar patterns of diversity and abundance have been observed in mammalian communities (Roy et al., 1995), non-vascular plant communities (Crites and Dale, 1995), and wood-decomposing insects (Martikainen et al., 1999).

Natural Dynamics

Dynamics refers to the origin and loss of old-growth stands over time. In Alberta, most stands are initiated by fire, though insect damage can also be an initiating factor. Because fires in the boreal forest are relatively common, most patches of regenerating forest are re-burned before they actually reach old-growth status (Johnson et al., 1998). In stands that reach the old-growth stage (Table 8.1), the sporadic mortality of individual large mature trees produces gaps that are repopulated by new trees, enabling the stand to persist indefinitely (Kneeshaw and Bergeron, 1998; Cumming et al., 2000).

On upland sites (the focus of most northern forestry operations), white spruce and aspen usually regenerate together after fire, producing mixedwood stands (Lieffers et al., 1996). If white spruce growth is vigorous it will suppress the regeneration of new aspen, and the stand will become progressively dominated by white spruce. However, in many cases the recruitment of white spruce after fire is delayed because a source of seeds is not sufficiently close or because the fire was not hot enough to prepare a suitable seed bed, among other factors (Lieffers et al., 1996; Greene et al., 1999). The result is an increase in the length of time it takes to achieve spruce dominance — the so-called “extended mixedwood stage” (Cumming et al., 2000). For some stands multiple generations of spruce trees may be required before conifer dominance is achieved (Cumming et al., 2000). Consequently, the age of trees in white spruce stands will often underestimate the true age of the stand, sometimes by a large margin (Cumming et al., 2000).

The generation of white spruce stands through the extended mixedwood pathway requires that stands escape burning for very long periods. Under the current fire regime this might be an uncommon occurrence if all stand types had an equal probability of burning. However, recent research by Cumming (2000) has shown that the probability of burning in aspen stands is extremely low until the proportion of spruce exceeds approximately 50%.

Abundance and Distribution

Current Age Structure of the Forest

The only forest inventory providing provincial coverage is the Alberta Phase 3 inventory (Anonymous, 1985). Phase 3 inventory is based on aerial photography flown between 1970 and 1984. It is regularly updated by the Forest Service to account for forest harvesting and fires. The age of stands is estimated from known relationships between tree height and age, specific to each stand type, and limited field checking. The township location of each stand is recorded, permitting spatial analysis at the township scale.

The age structure of the forest derived from the Phase 3 inventory is generally consistent with our understanding of stand dynamics. Representation of deciduous stands declines markedly after 80 years, whereas white spruce stands only reach their peak at 140 years (Fig. 8.1). Given that aspen stands are relatively resistant to burning, this pattern is further evidence of the transition of stands from aspen to white spruce through the mixedwood stage.

A significant anomaly in the Phase 3 inventory is the relative paucity of stands in the 0-40 year age class (Fig. 8.1). There are two main reasons for this. First, there was a relatively low rate of fire in the 1960s and 1970s (see Fig. 6.2). Second, no new aerial surveys have been conducted since 1984; therefore, young regenerating stands have not been properly accounted for over the past two decades.

Using Phase 3 inventory and the definitions of old-growth listed in Table 8.1, 26.5% (by area) of commercial forest stands in Alberta are currently in the old-growth stage. The proportion of mixedwood stands in the old-growth stage is substantially greater than for either pure deciduous or pure white spruce stands (Fig. 8.2). This same pattern was described by Lee et al. (2000) in northeast Alberta using more detailed old-growth criteria and data derived from 1129 sample plots. The high proportion of old-growth among mixedwood stands is consistent with the stand dynamics described earlier. Old-growth characteristics are acquired early in these stands, due to the early mortality of aspen trees. In addition, the relatively fire-resistant extended mixedwood stage allows many stands to attain an advanced age before burning or converting to pure white spruce (Lee et al., 2000; Cumming, 2001).

For a variety of reasons the measures of old-growth presented in Fig. 8.2 represent minimum estimates. First, the criteria used to define old-growth were conservative. For example, although aspen stands often begin to acquire old-growth

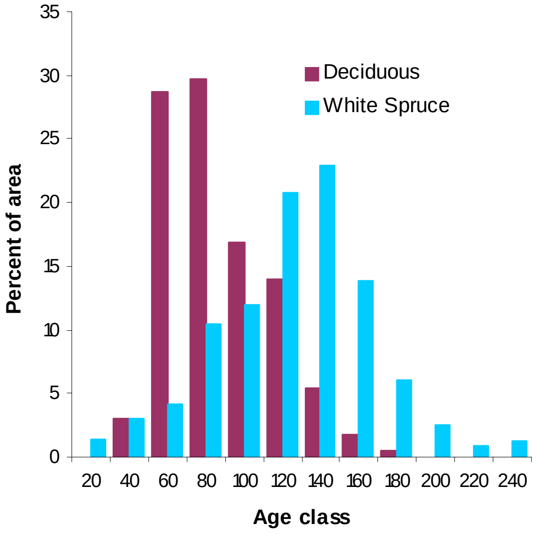


Fig. 8.1. The age structure of forest stands in Alberta, by stand type (denominator = total stand area, by type). Data from Phase 3 inventory current to 2000.

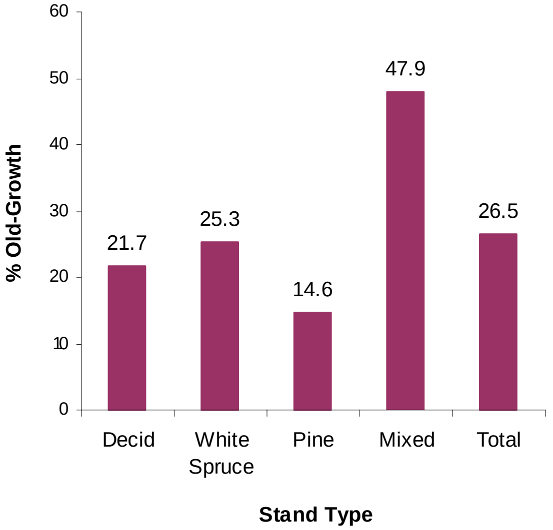


Fig. 8.2. Quantity of old-growth (as defined in Table 8.1), expressed as a percentage of the total stand area for each stand type. Data from Phase 3 inventory current to 2000.

characteristics by 85 years of age (Timoney, 2001), only stands greater than 100 years were included in the analysis. Second, as stands attain the uneven age structure characteristic of old-growth, it becomes increasingly difficult for photo-interpreters to accurately identify and age the trees that initiated the stand. This invariably leads to underestimation of the true age of older stands (Cumming et al., 2000). Furthermore, once the initiating cohort of trees dies, the photo-interpreted age of the stand will effectively become fixed, even though the stand may persist for many additional decades before burning. This applies particularly to aspen stands because they reach old-growth status quickly but are relatively resistant to burning (Cumming, 2001). It also applies to stands in the extended mixedwood pathway, and to pure spruce stands that were generated through the extended mixedwood pathway (Cumming et al., 2000).

Forest harvesting, which specifically targets old-growth stands (AEP, 1994a), is another factor resulting in underestimation of the proportion of old-growth naturally occurring on the landscape (Timoney, 2000). The greatest impact has been on white spruce, which has been harvested in Alberta, at increasing rates, for many decades. Some of the impact of harvesting may have been offset by fire suppression; however, available evidence suggests that such compensation has not been complete (see Chapter 6).

Another approach to the quantification of old-growth is to mathematically calculate (using probability theory) the expected proportion of old-growth on the basis of the rate of burning (Johnson and Van Wagner, 1985). Simply put, the greater the rate of fire, the more likely a stand will burn before reaching old age, and vice-versa. Given the average rate of burning in northern Alberta since the provincial fire database was initiated in 1960 (0.4% per year), 57% of the forest should be greater than 140 years of age. Table 8.2 provides results for additional combinations of age at old growth and rate of burning. Overall, the amount of old-growth predicted on the basis of the rate of burning is substantially greater than the amount recorded in the Phase 3 inventory (Fig. 8.2), even if the rate of burning was substantially higher before we started keeping records. This is additional evidence that forest stands are older than the age of currently existing trees, and that our estimates of the amount of old-growth are quite conservative.

Spatial Distribution of Old-Growth

The distribution of old-growth is influenced by factors that affect the probability of burning, factors that affect regeneration, and an element of randomness. The probability of burning is affected by local topography, moisture regime, and climate, as well as transient factors such as stand type (Timoney, 2000; Cumming, 2001). Regeneration (particularly the determination of stand

Table 8.2. Expected percentage of area classified as old-growth when calculated from the average annual rate of burning.[1]

Old-Growth Age Criterion	Expected % Old-Growth[2] Burn = 0.4%	Burn =1%
> 100	67	37
> 120	62	30
> 140	57	25

[1] Results derived from the negative exponential function, which assumes random burning at a fixed rate (Johnson and Van Wagner, 1985).

[2] Expected percentage of landscape in old-growth given an annual rate of burn of 0.4% and 1%. Actual rate of burn recorded in northern Alberta: 1960-2000 = 0.40%; 1980-2000 = 0.63%. Source: ASRD, 2002.

type) is influenced by persistent factors such as soil type and moisture regime, and transient factors such as the availability of a seed source (Greene et al., 1999). Together, these various factors produce patterns in the distribution of old-growth that are apparent at different scales.

At the stand scale, particularly on the boreal plain, the basic pattern is set by the large but infrequent fires that are responsible for most burning (Johnson et al., 1998). These fires rejuvenate large regions of forest, producing a relatively even-aged forest matrix (Fig. 8.3). Within this matrix are islands of old-growth, representing trees that escaped burning, and islands of young forest, arising from the many small fires that occur each year (Fig. 8.3). The islands of old-growth are often downwind from water bodies and other firebreaks, and so are generally not random in their distribution (Eberhart and Woodard, 1987; Fairbarns, 1991; Timoney, 2000). However, the exact pattern changes from fire to fire because of differences in wind direction and other transient factors. As a general rule, the rate of fire increases with distance from a water body (Larsen, 1997). In the boreal forest the rate of burning is sufficiently high that it is rare for the matrix itself to reach old-growth status before being reburned (Johnson et al., 1998).

At the regional scale, additional patterns are apparent. In particular, there is a clear association between old-growth and large river corridors (Fig. 8.4). The abundance of old-growth within large river valleys reflects a low rate of burning relative to upland areas due to sloping banks that retard the advance of fire, increased moisture, and pres-

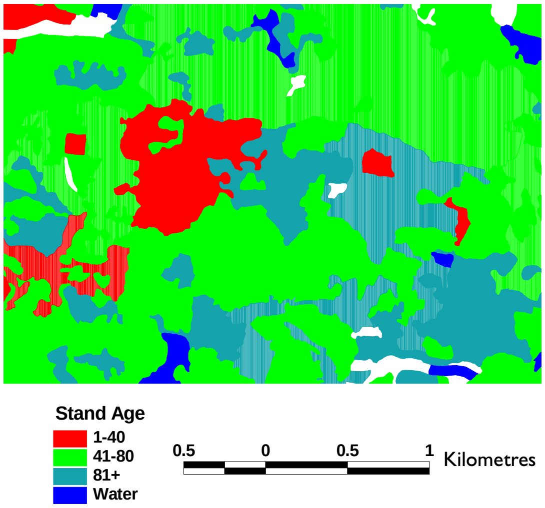
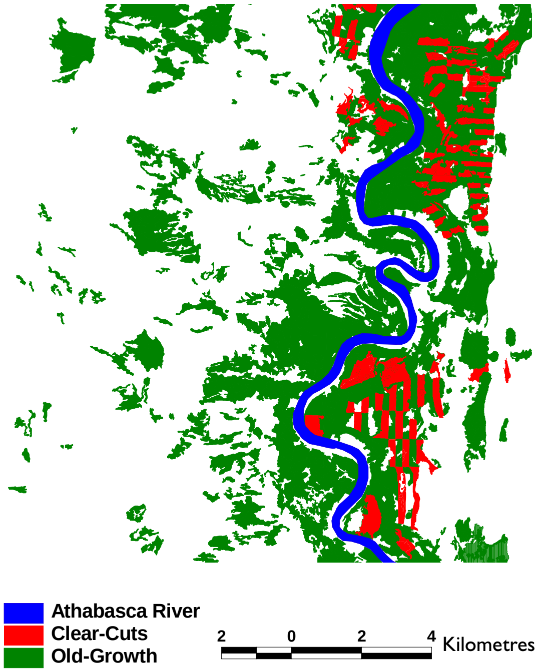


Fig. 8.3. Typical pattern of stand age structure in the boreal mixedwood forest. (Map: Forest Watch Alberta)



Fib. 8.4. Distribution of old-growth forest (> 100 years) along the Athabasca River, north of Calling Lake. Recent clear-cuts (0-5 years old) are also shown. (Map: Forest Watch Alberta)

ence of open water (Timoney et al., 1997). The larger the watercourse, the more likely that this pattern will be observed. Another pattern clearly apparent at the regional scale is the preferential targeting of old-growth stands for harvesting (Fig. 8.4).

At the provincial scale, it is evident that relatively few townships within the boreal plain contain more than 25% old-growth of commercially-harvested species (Fig. 8.5). This is because old-growth in the boreal forest is widely distributed, and rarely clumped into specific regions, with the exception of large river valleys. This pattern also reflects the simple fact that almost a third of northern Alberta is comprised of non-merchantable peatlands and wetlands of various types (See Fig. 1.5).

In contrast to the boreal forest, the representation of commercially harvested old-growth in the East Slopes is relatively high throughout (Fig. 8.5). This is primarily because most townships there contain a high proportion of commercial forest (typically comprised of long-lived coniferous species) and few peatlands are present. Differences in drainage patterns, soil type, and climate, all contribute to the observed differences in forest composition (and hence old-growth) between the East Slopes and boreal regions. Whether there are also significant differences in the rate of fire between these two regions, contributing to observed differences in the occurrence of old-growth, is an open question. On one hand, the irregular topography of the foothills may limit the spread and ultimate size of fires, relative to the boreal plain. However, the deciduous and mixedwood stands typical of the boreal forest appear to have intrinsically lower probabilities of burning than the pure coniferous stands that dominate the foothills (Cumming, 2000).

Management of Old-Growth

Current Management

Forestry policy in Alberta continues to be fundamentally based on sustained-yield management (AEP, 1996). Sustained-yield means that forestry companies must ensure that their rate of harvest does not exceed the rate of tree growth; however, there are no requirements for maintaining old-growth on the landscape. In fact, the general practice, as reflected in the *Alberta Operating Ground Rules*, is to cut the oldest trees first (AEP, 1994a).

Because old-growth stands support the greatest diversity of forest species, the current policy of old-growth liquidation will have a significant detrimental impact on biodiversity (Stelfox, 1995: *viii*). Species with highly specialized habitat requirements restricting them to old-growth stands will be affected earliest and most severely. Studies on forest birds (Benkman, 1993; Schieck and Nietfeld, 1995), bats (Crampton and Barclay, 1998), insects (Niemela et al., 1993) and non-vascular plants (Crites and Dale, 1995) have all concluded that population declines of specialist species are likely to occur if old-growth is eliminated from the landscape. Other species that are found in multiple age classes but have their highest abundance in old-growth will also be affected. In some cases the impact will be large, because individuals currently observed in younger age classes will disappear once the core old-growth population, responsible for most reproduction, is eliminated.

Widespread declines in old-growth species have not yet been observed in Alberta, because substantial tracts of old-growth remain (though systematic surveys of rare species have never been conducted). However, Finnish and Scandinavian forests, where old-growth stands have been greatly

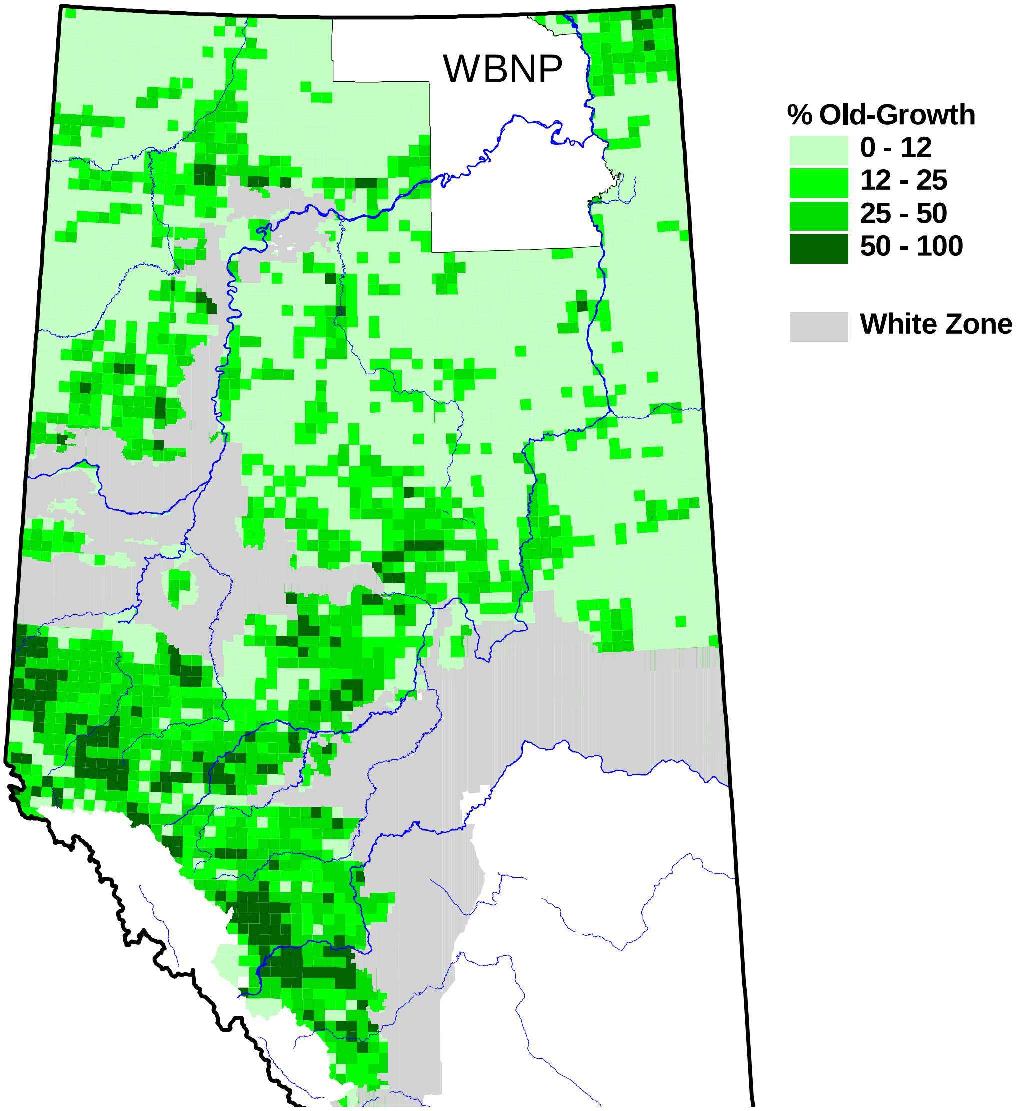


Fig. 8.5. Percentage of old-growth forest (> 100 years) per township. Forest types that are not commercially harvested are not included. Data from Alberta Phase 3 inventory, current to 2000.

reduced, provide evidence that concerns about old-growth species are well founded (Virkkala et al., 1994; Niemela, 1999). In Finland, several bird species that are old-growth specialists are in decline and their distribution is becoming concentrated in nature reserves, where substantial quantities of old-growth persist (Virkkala et al., 1994). Several species of insects that are now rare or extinct in Finland have been found in abundance immediately across the border in Russian Karelia, where old-growth has not been eliminated by harvesting operations (Siitonen and Martikainen, 1994). Overall, it is estimated that forestry operations in Fennoscandia have resulted in the decline of many hundreds of species (Niemela, 1999).

A Strategy for the Management of Old-Growth

Among biologists working on boreal systems there is a clear consensus that the retention of an appropriate amount of old-growth is necessary for the maintenance of forest biodiversity (Benkman, 1993; Bergeron et al., 1999; Burton et al., 1999; Niemela, 1999; Timoney, 2000). Studies commissioned by the Government of Alberta have also made recommendations to this effect:

> *Provincial government agencies and the forest industry are therefore encouraged to: . . . recognize the existence of a distinctive "old-growth" stage in aspen mixedwood forests and ensure that appropriate frequencies of older seral stages are maintained in the boreal forest landscape* (Stelfox, 1995: viii).

> *Maintaining current levels of forest-based biodiversity within the boreal forest natural region will require perpetuation of the full range of seral stages. There is no doubt that the most important and threatened age-class is old-growth* (AEP, 1998: 46).

The need to retain older age classes of forest is also specified in the Alberta Forest Conservation Strategy (AFCSSC, 1997: 10).

If old-growth is to be retained on the landscape with the objective of maintaining its associated biodiversity, then a comprehensive strategy for old-growth management is required. This strategy must include: (1) appropriate targets for the quantity of old-growth to be retained, (2) targets for the spatial distribution of old-growth, including the distribution of patch size, and (3) a dynamic planning framework designed to ensure that the targets will be achieved continuously (i.e., without periodic gaps). All targets must be defined by stand type.

Amount of Old-Growth to be Maintained

In general terms, the appropriate quantity of old-growth is defined by the Natural Disturbance Model (NDM) of forest harvesting. Under this model the target would be the amount of old-growth that occurs as a result of natural cycles of disturbance (fire) and forest regeneration. Although the NDM is conceptually straight-forward, it is difficult to apply in practice (see Chapter 7). Our estimates of the rate of burning and our understanding of forest regeneration are both inadequate for predicting the patterns of old-growth that would arise from any specific fire regime.

An alternative approach for defining old-growth targets is to utilize the patterns present in the existing forest. The Alberta Phase 3 inventory is the only data set providing provincial coverage, so it will have to be used for initial guidance (e.g., Fig. 8.2). It is best to use regional estimates because locally-derived estimates are usually biased by the impact of large historic fires (or lack thereof) (Cumming et al, 1996). However, systematic errors in the photo-interpretation of stand age and the cumulative impact of historical logging imply that the Phase 3 inventory underestimates the natural amount of old-growth, possibly by a large margin (Cumming et al., 2000; Timoney, 2001). On the other hand, fire suppression is likely to have had at least some effect, even if it is not as large as sometimes claimed (See Chapter 6). Further research will be required to determine whether these two biases cancel each other out, or whether adjustments to the initial old-growth targets are required.

Spatial Distribution of Old-Growth

The NDM can also be used to define targets for the spatial distribution of old-growth. As previously discussed, the basic pattern is generated by fire, but individual sites differ in their susceptibility to burning (Angelstam, 1998). It follows that harvesting should be concentrated where the probability of burning is highest, and sites that are unlikely to burn should be harvested at a very low rate (if at all). Scandinavian researchers have formalized this concept into the so-called ASIO model, which stands for Absent, Seldom, Infrequent, and Often (Angelstam, 1998). Under this model, sites are assigned an ASIO category on the basis of estimated fire frequency (using variables such as proximity to water, slope, aspect, etc.) and their rate of harvest is set accordingly.

Another aspect of spatial pattern that needs to be considered is patch size (where patches are contiguous stands of the same age class). Conventional harvesting practices produce cut-blocks of relatively fixed size, and the old-growth stands that will eventually arise from such practices will have minimal variability in size (Fig. 8.6). Of particular concern is the lack of production of large old-growth patches, as some species prefer the interior of stands away from the effects of exterior edges (Mladenoff et al., 1993; Paton, 1994). To avoid such problems, the targeted objective should be to maintain a natural distribution of patch sizes.

Operationally, the achievement of a natural patch-size distribution implies the introduction of variability into harvesting practices at multiple scales. Small patches of old-growth (i.e., < 2 ha) are typically most numerous and can best be generated by leaving clumps of live trees within harvested stands and by leaving small isolated stands unharvested. Variability of medium-sized patches (2-60 ha) can best be achieved by varying the size of harvest blocks (Fig. 8.6). Finally, the production of large patches of old-growth can be accomplished by designing the layout of harvest blocks such that over time large contiguous patches of old-growth are produced (Ohman and Eriksson, 1998). In some cases it would be desirable to aggregate logging at the township scale over a period of 20-30 years, to simulate the impact of a very large fire, and then remove all roads and leave the entire region untouched for 100 or more years.

Landscape-level Planning

The implementation of the old-growth management strategy described above is an extremely complex undertaking. To summarize, there are targets for the quantity of old-growth, by stand type, targets for the spatial distribution of old-growth, based on ASIO site factors, and targets for the distribution of old-growth patch size. These targets are to be maintained continuously, in the face of ongoing forest harvesting and wildfire, and in spite of initial age distributions that may be highly skewed in local management areas. Needless to say, implementation will have to occur in stages, as the required data and capacity for planning are acquired.

Initial priority should be given to retaining appropriate amounts of old-growth on the landscape. This can be achieved by allowing a portion of the older stands to escape harvest. Operationally, the objective is a tapered age distribution, as

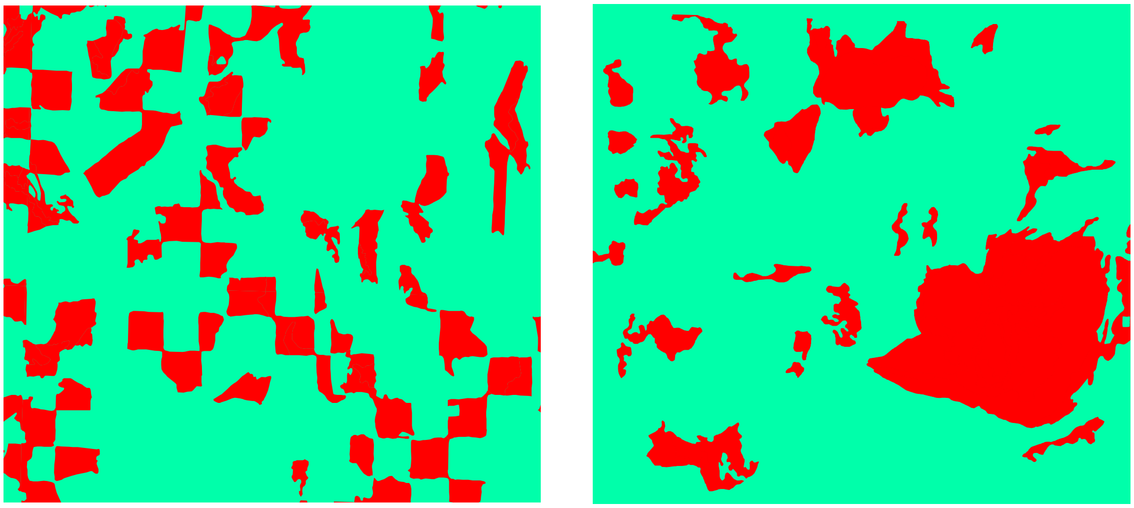


Fig. 8.6. Spatial pattern of harvest blocks. On the left are blocks cut within the past five years, demonstrating the conventional pattern. On the right is a pattern designed to maintain the natural distribution of old-growth patch sizes. The total area of harvest is approximately the same in both figures. (Map: Forest Watch Alberta)

described by Burton et al. (1999) (Fig. 8.7). The total amount of old-growth and age of the oldest stands would be based on provincial Phase 3 inventory data, by stand type, as previously described. The intent is to achieve these targets in perpetuity; however, it is recognized that skewness in the existing age structure in some forest management areas will result in transient deficiencies in some age classes at the regional level. This is not a concern as long as provincial targets are maintained. The expected impact of fire and other disturbances must be included in harvest plans so that the targeted distribution of old stands is actually achieved (Burton et al., 1999).

Targets for the spatial distribution of old-growth can best be achieved in the short-term through the establishment of old-growth reserves where no harvesting will occur over the next 20-year planning cycle. An obvious candidate for the core of this reserve is the existing system of ripar-

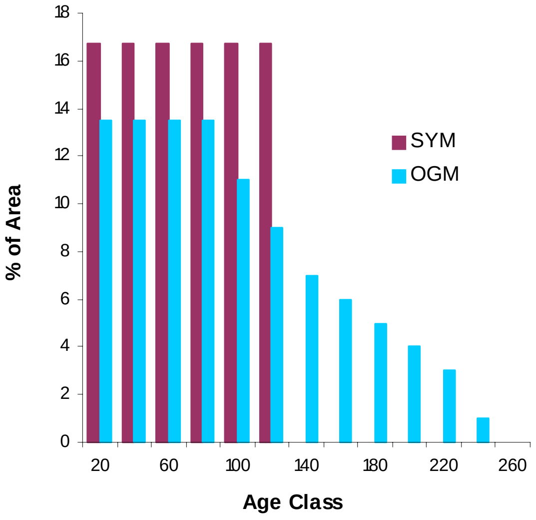


Fig. 8.7. A comparison of hypothetical target age structures under sustained-yield management (SYM) and old-growth management (OGM).

ian buffers (Cumming and Schmiegelow, 2001). The rate of burning in riparian areas is lower than in the surrounding uplands (fulfilling ASIO criteria) (Larsen, 1997) and they are able to serve as ready-made movement corridors, connecting old-growth patches throughout the landscape (Machtans et al., 1996). Because no harvesting is currently permitted in riparian buffer zones, there would be no impact on current harvest levels.

Any remaining large contiguous patches or local clusters of old-growth should also be incorporated into the reserve system. These large patches should account for a substantial portion of the total old-growth target area (Fairbarns, 1991; Niemela, 1999). Without special interim protection it is likely that remaining large patches of old-growth will be fragmented before a comprehensive system of dynamic planning is in place. Fragmentation by roads and seismic lines is a related issue that also needs to be addressed, likely by restricting new linear development in the reserve until it becomes part of the active land base again.

Large stands of old-growth white spruce, especially along major river valleys, should be given priority for protection because only a fraction of historic amounts of this stand type remain after decades of intensive harvesting (Timoney, 1996; AEP, 1998: 46). Furthermore, recent studies have demonstrated that the risk of fire in pure coniferous stands is substantially higher than in aspen-dominated mixedwoods (Cumming, 2000). Therefore, white spruce regeneration based on monoculture plantations may expose stands to excessive risk of fire (vs. mixedwood regeneration), and thereby fail to produce adequate amounts of old-growth.

The initial system of extended harvest ages and fixed old-growth reserves will achieve old-growth objectives in the short-term and keep options open for the future. However, fire will eventually fragment or completely obliterate most remaining large patches of old-growth (Johnson et al., 1998). Therefore, as soon as possible we need to implement a dynamic system of planning where new old-growth stands are continually produced to replace others that may be lost (especially the larger patches). Prototype computer models capable of such spatially-explicit harvest planning have been developed (e.g., Ohman and Eriksson, 1998; Baskent, 1999); however, they are not yet ready for commercial application. Additional data, including an ASIO classification of the landscape and better estimates of the amount and distribution of existing old-growth, are also required before such a system can be fully implemented.

Stand-level Management Issues

The old-growth management strategy, as part of a broader implementation of the NDM, should include a transition to mixedwood management wherever applicable. Mixedwood management involves the regeneration of white spruce through a natural mixedwood phase instead of current plantation management techniques that are designed to produce monocultures (Lieffers and Beck, 1994). Mixedwood stands are a prominent component of boreal old-growth and need to be maintained on the landscape (Stelfox, 1995: *viii*). With mixedwood management in place it will also be possible to define and achieve a more realistic target age structure for white spruce (e.g., Fig. 8.1), in place of the artificial age structure generated through monoculture regeneration (e.g., Fig. 8.7).

Another important component of old-growth management at the stand-level is the retention of live merchantable trees at the time of harvest. Larger clumps of such trees serve to maintain old-growth at the micro-scale, simulating the small unburned islands that typically remain after fire (Eberhart and Woodard, 1987). Residual live trees also provide at least some of the structural legacy that normally passes from the pre-fire stand to the new regenerating stand (Lee et al., 1997). The legacy of the pre-fire stand is responsible for much of the species diversity in young regenerating stands. It should not be construed, however, that leaving residual structure at the time of harvest reduces the need for old-growth (Schieck et al., 2000). As previously described, old-growth stands have the highest levels of species diversity, including many specialist species that are not found in other age classes (Niemela et al., 1993; Crites and Dale, 1995; Kirk et al., 1996). Furthermore, most species that are found in both young and old stands have their highest abundance in old-growth stands (Stelfox, 1995: *vii*; Schieck et al., 2000). It is questionable whether these species would persist if core breeding populations in old-growth stands were eliminated (Schieck et al., 2000).

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