Interior Douglas-fir and Selection Management at the UBC/Alex Fraser Research Forest

Forest Management for Mule Deer Winter Range

Ken Day, R.P.F.[1]

Prepared for:
IUFRO Uneven-aged Silviculture Symposium
Corvallis, Oregon
September 15-19, 1997

Abstract

The Alex Fraser Research Forest is one of two forests operated by the University of British Columbia Faculty of Forestry. It is public land managed under license from the Ministry of Forests. The Knife Creek block is 3,487 ha in extent, and is primarily situated in the dry cool subzone of the Interior Douglas-fir biogeoclimatic zone. Management plans for the Knife Creek Block show mule deer winter range to be the highest priority for land use -- timber harvesting may proceed provided it does not impair winter range values. Mule deer in the Cariboo Forest Region are very sensitive to snow depth, and require winter range habitat in low-snowfall areas with appropriate forest cover to provide snow interception and food. Dry Douglas-fir forests of an uneven-aged structure meet all of these requirements. Current attempts to integrate mule deer winter range and industrial timber harvesting are focused on low-volume removals with long re-entry periods which provide a clumpy arrangement of wide-crowned old trees. These harvest methods have been designed to remove timber from stands without negatively impacting mule deer habitat values. Recent work at the Research Forest indicates, however, that a formal approach to harvesting by the selection method may yield improvements in both mule deer habitat and timber production. Stand structure objectives, cutting cycle, and marking guides are discussed.

Introduction

The UBC/Alex Fraser Research Forest was created in 1987. The Research Forest is managed to provide an optimal environment for education, research, and demonstration in integrated forest resources management. Comprised of two distinct blocks of forest land near Williams Lake in the Cariboo Forest Region, the Forest is managed under license from the provincial government.

The southern-most block of the Research Forest is known as the Knife Creek block[2], and is 3,487 ha in area located on very gentle terrain adjacent to the San Jose Valley. The Knife Creek block is predominantly located in the dry cool subzone of the Interior Douglas-fir biogeoclimatic zone (IDFdk after Hope et al. 1991). The mean annual precipitation is 444 mm with approximately half falling in the growing season, and the mean

---

[1] Manager, UBC/Alex Fraser Research Forest, Williams Lake, BC, Canada, V2G 4N5.
[2] The Knife Creek Block of the UBC/Alex Fraser Research Forest is located in the Williams Lake Forest District, Cariboo Forest Region, British Columbia. Longitude 121º48’ W, latitude 52º 03’ N.

annual temperature is 3.0ºC (Day 1997a). The mean frost free period is 79 days (Hope et al. 1991). Because these forests are dry, they have a relatively low productivity.

The climax tree species is Interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco), which is a widely distributed species with a very broad ecological amplitude. In the dry parts of its range, it grows in an uneven-aged fire-dominated sub-climax. Historical fire frequency in the IDFdk at Knife Creek has been determined to be between 16 and 18 years (Daniels et al. 1995), and these frequent fires dominated the development of the natural stands. Natural precedents indicate that interior Douglas-fir is well suited to uneven-aged management regime, at least in parts of its range.

Large timber and proximity to highways and manufacturing plants has made the uneven-aged Douglas-fir forests of the Cariboo highly desirable for timber harvesting. Their low elevation and limited snow pack makes the forests important winter habitat for mule deer (Armleder et al. 1986). The forests are used for cattle grazing, and proximity to population centres makes dry-belt fir forests important for public recreation. Such multiple demands on the land base impose complex forest management objectives, and these objectives direct the prescriptions for forest management.

Silviculturists writing prescriptions for timber harvesting on mule deer winter range must consider the habitat needs of the deer, and the silvics of interior Douglas-fir. Prescribed harvesting should be used as a means to improve and maintain mule deer winter range; while meeting timber harvesting objectives. The use of selection management offers a structured means to satisfying both objectives.

Interior Douglas-fir at Knife Creek

Interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) tends to regenerate naturally in canopy gaps after disturbance. On most sites in the IDFdk3, seedbed is generally available, seed supply is plentiful, and the hot and dry environment is moderated by the shelter of the surrounding uneven-aged stand. Douglas-fir from Knife Creek and the surrounding area has been described as moderately shade tolerant (Chen et al. 1995), so new regeneration is able to perform reasonably well in the shaded conditions.

Regeneration tends to accumulate and grow into very dense thickets of saplings. Thickets at high densities tend to stagnate because the sites are moisture limited, and even the most vigorous trees are not able to shade out competing neighbours. Relatively few trees die in this state, but very little height growth or diameter growth takes place. Tree and stand vigour are reduced, growth declines, and the risk of insect or disease attack increases. It is presumed that this condition persists until some form of disturbance breaks up the thickets -- fire, insects, disease, snow and ice damage, or cutting.

Uneven-aged management is well suited to Douglas-fir at Knife Creek, because it offers relatively frequent cutting entries to stabilize stand structure, and ensures growth of all size classes (Nyland 1996). Interior Douglas-fir responds well to thinning, and density control can improve:

- stand structural characteristics suitable to management objectives;
- tree and stand growth rates (Marshall, unpublished data, 1997); and
- stand vigour, health, and stability (Nyland 1996).

Mule Deer

The Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) ranges from the Yukon in northern Canada nearly to the US-Mexico border and east into the prairies of the US and Canada (Geist 1990). In the Cariboo Forest Region of central British Columbia, mule deer are at their northern limit of continuous high-density distribution (Mule Deer Winter Range Strategy Committee 1996).

Mule deer have been studied in the Cariboo for more than twenty years. The numerous published and unpublished reports prepared by staff of the BC Forest Service and BC Environment extensively document mule deer ecology in this region. A good summary of that research is provided by the Mule Deer Winter Range Strategy Committee (1996), which is referenced throughout the discussion which follows.

Forage

Mule deer are relatively selective feeders that require ample high-quality forage to balance their seasonal energy budgets. Whereas spring and summer forage is of high quality, forage quality declines in the fall and winter when plants transfer their nutrients for storage in stems and roots. Further, deers' energy demands increase in the winter as temperatures drop, movement becomes more difficult, and high-quality feed is covered by snow. Energy must therefore be balanced for the year as a whole, so that stored energy from spring and summer provides for inadequate forage in winter months.

Douglas-fir foliage forms an important component of the mule deer winter diet, averaging 65% of the winter diet, and accounting for up to 89% of the diet in some months. Foliage from trees older than 100 years of age is most valuable, and foliage from young trees is virtually unused. This foliage is available to mule deer in the form of litterfall, wind-thrown trees, or broken branches. In addition to the Douglas-fir foliage, litterfall often includes arboreal lichens which are favored by mule deer.

Cover

Forest structural attributes provide three benefits to mule deer; snow interception cover, thermal cover, and security cover. As snow depth increases, the energy required for locomotion increases exponentially. If forest canopies are available to intercept snow, reduced snow depth reduces energy demands and makes ground forage more accessible. Forests also reduce wind velocity and radiative heat loss, reducing energy demand. is by The screening effect of trees provides security cover, which reduces the energy demands from flight and stress.

Winter Range Requirements

Mule deer in the Cariboo Forest Region range through widely dispersed and varying habitats in the late spring, summer and fall. In late fall, however, mule deer must migrate to winter ranges that provide their forage and cover requirements, traveling as much as 100 km. Winter ranges are generally on warm aspects (south or west facing) covered by uneven-aged Douglas-fir forests. A mixture of open-, moderate-, and closed-canopy conditions provides access to different habitats, each of which assume a special importance as winter conditions change. Winter ranges are generally adjacent to grasslands, which provide the earliest high-quality forage available in the spring that is critical to over-winter survival.

Mule deer have fidelity to particular winter ranges, and may cross other suitable winter ranges to arrive at "their own" range.

Winter ranges are in areas with climates conducive to survival: snowfall accumulation and duration; temperature; and wind. Winter ranges with high snowfall require greater snow interception cover.

Large old Douglas-fir is a prominent component of winter range in the Cariboo Forest Region -- their wide deep crowns are comprised of stiff branches which effectively intercept snow and hold it off the ground. A clumpy arrangement of these large trees further increases their ability to intercept snow -- several interlocking crowns are more effective than the same number of trees arranged uniformly. Large old trees also provide litterfall forage. Litterfall is increased by the clumpy arrangement of trees, since their proximity increases the amount they bump into each other and the resulting breakage of fine twigs and small branches. Uneven-aged management assures a continuous supply of large old Douglas-fir through time.

Current Practise on Winter Range

Mule deer winter range in the Cariboo Forest Region is currently managed according to a handbook produced by the Ministry of Forests (Armleder et al. 1986) after six years of study of mule deer in the Cariboo[3]. The handbook advocates "low-volume selective harvesting" by the faller's choice method.

Harvest intensity varies within the cut block depending upon topographical position. Cool aspects and gully positions are harvested more heavily than warm aspects and ridges, in recognition of the differing value of those features to deer. Harvest targets are set as a proportion of the cruised volume, typically 20%. Selection of trees for felling is left to the faller, after training in the relative values of different types and positions of trees.

The handbook method advocates the maintenance of an "inverse-j" diameter distribution, but stops short of stipulating target stand structures. Since the publication of the handbook, harvesting on winter ranges have followed its methodology, and companies preparing harvest plans are required to develop target stand structures. Implementation of the harvest prescription is still left to faller's choice. Research and monitoring in mule deer and winter range ecology have continued since the publication of the handbook, but little effort has been devoted to phrasing winter range management objectives in succinct silvicultural terms with consistent implementation.

As a component of a broad land use planning process, a mule deer winter range strategy has been written for the Cariboo Forest Region (Mule Deer Winter Range Strategy Committee 1996). That strategy bases decisions on harvesting on the condition of each individual winter range, as determined from forest cover maps. The determining feature of timber availability is the proportion of low, medium, and high crown closure. Armleder et al. (1986) recommend that mule deer winter ranges which receive moderate snow fall should have an equal proportion of each of the three crown closure classes to provide suitable cover and forage. According to the Mule Deer Winter Range Strategy Committee (1996) the Knife Creek winter range has 32% high, 16 % moderate, and 55% low crown closure conditions due to past diameter-limit cutting. The strategy therefore concludes that no harvest of Douglas-fir is currently available except for salvage of mortality caused by bark beetles or other damage.

Proposed Prescription

Work has been under way on the Research Forest to develop silvicultural prescriptions for mule deer winter range that:

- meet the intent of the handbook method;
- enhance or maintain winter range values;
- deliver clear guidance to harvesting;
- are practical and achievable; and
- are measurable.

The prescription outlined below will be implemented throughout the Knife Creek block after review by government silviculturists and wildlife biologists. It is expected that a period of operational trials with intensive monitoring will be required.

Note that all discussions of stocking and density exclude any trees less than 7.5 cm dbh.

[3] Much of this research took place on the Knife Creek mule deer winter range, before the creation of the UBC/Alex Fraser Research Forest.

Stand Management Objectives

The goal of managing mule deer winter range is an uneven-aged stand of Douglas-fir that provides a continuous supply of large crowned trees greater than 120 years of age. Trees should attain a large size, and should develop wide and deep crowns. Stand structure should hold most of the basal area in large trees, which are arranged in groups not exceeding half a tree-length in diameter. Stocking will be controlled in all diameter classes, by reducing the density to target levels before the onset of competition-induced mortality. A reserve of approximately 10% of the residual basal area should be retained in trees greater than the maximum diameter class, to contribute biodiversity and amenity benefits. Trees cut from the stand will provide sawlogs of moderate quality due to large branch size. Marking intensity will vary by topographical position in recognition of the relative value of various topographical positions to deer winter habitat.

Target Stand Structure (BDq)

Residual Basal Area (B)
18 m2/ha (DBH>7.4 cm)

Using radial increment data developed from 794 trees on 39 plots, Day (1997b) took two different approaches to calculating residual stocking for Knife Creek.

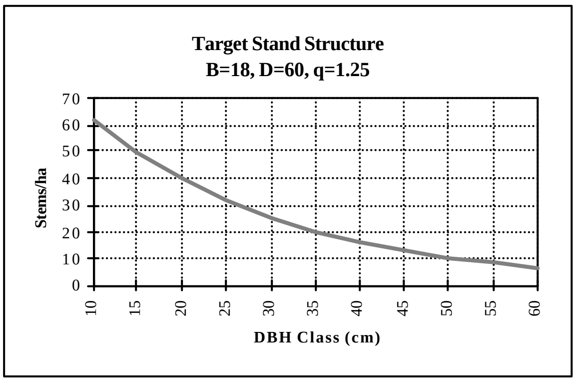

Figure 1: Target stand structure for Knife Creek mule deer winter range.

1. Langsaetter's curve (as described by Long (1988))was fit using regression techniques, and B-level stocking from Langsaetter's curve was estimated to be 17.5 m^2/ha.

2. A Gingrich Chart[4] was created for Knife Creek, using maximum density measured on the 39 plots as the reference level. Upper and lower limits of stocking as suggested by Long (1985) for even-aged stands were set -- 60% and 35% of maximum density respectively. Given the target stand structure described, the quadratic mean diameter (Dq) is calculated as 28.4 cm. According to the Gingrich Chart (Figure 2) the B-level stocking for 28 cm quadratic mean diameter is 17.85 m^2/ha.

Maximum Diameter (D)
60 cm dbh

Since the stand management objectives require that a significant component of the stand be greater than 120 years of age, large maximum diameters are implied. Fiedler (1995) recommends that maximum diameter should be set either at the size where growth slows, or beyond which few trees grow.

- Data reported by Day (1997b) indicate that diameter growth of Douglas-fir at Knife Creek slows down between 50 and 60 cm dbh.
- Few trees at Knife Creek grow beyond 60 cm dbh -- generally less than 10 trees/ha constituting about 10% of the stand basal area.

[4] Gingrich stocking charts were first described by Ginrich [sic] (1967), and are a simple expression of stocking as a proportion of a reference level. The chart displays the density of the stand by number of trees and basal area, and therefore implies the quadratic mean diameter of the stand.

Sixty centimetres therefore seems to be a suitable target for maximum diameter. A basal area reserve of 2 m^2/ha greater than 60 cm dbh is instituted, to recruit large snags and coarse woody debris (as recommended by Fiedler (1995)).

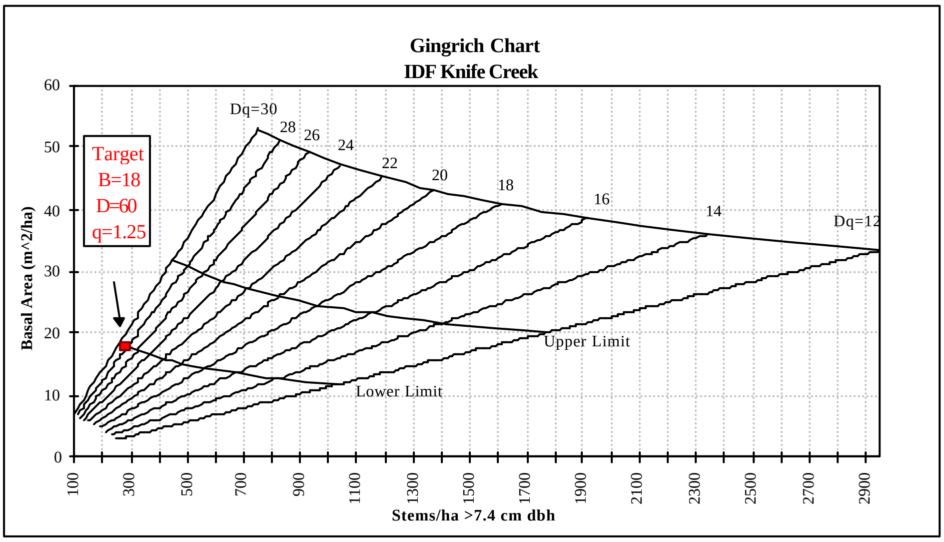

Figure 2: Gingrich Chart for Knife Creek after Day (1997b) indicating that the target stand is at minimum stocking.

Diminution quotient (q)
1.25

High q-factors concentrate stocking in small diameter classes, while low q-factors concentrate stocking in large diameter classes (Daniel et al. 1979; Fiedler 1995). Low q-factors produce better volume growth, since increment is being concentrated on larger stems (Marquis 1976; Leak 1988). Dry forests managed by uneven-aged methods typically employ very low q-factors to avoid overstocking and stagnation which could accompany higher q-factors (Becker 1995). Since the stand management objectives require large trees to provide forage and cover, a low q-factor is desirable. To employ a low q-factor on the first harvest in an unregulated stand invites over-cutting, however, and many authors suggest using a slightly higher q-factor in the first entry (Marquis 1976; Daniel et al. 1979; SIWG 1992; Fiedler 1995). By process of design, and considering the factors discussed here, a q-factor of 1.25 was selected.

Cutting Cycle

According to Davis and Johnson (1987) the cutting cycle is the cornerstone of the management prescription. The cutting cycle is a function of the level of residual growing stock and the basal area growth rate (Matthews 1991). Day (1997b) found that periodic basal area growth in Knife Creek averaged 4.2 m^2/ha per decade in unregulated stands (without considering mortality). Marshall and Wang (1996) found growth in Knife Creek (considering mortality) to be 3.4 m^2/ha per decade in unregulated stands. Marshall (unpublished data, 1997) has found average growth rates of 8.3 m^2/ha per decade in thinned stands at Knife Creek.

Short cutting cycles require large felling areas to produce a small volume (Matthews 1991), but assure the salvage of mortality and more constant control over stocking. Long felling cycles, on the other hand, reduce the area of each compartment and thereby improve the economic efficiency of the harvest (Matthews 1991). Longer cycles increase the risk of loss through mortality and reduce the stocking control exerted. Matthews (1991) also states that long cycles with small compartments favor more light-demanding species, because of relatively more intensive cutting.

Figure 2 above indicates that the upper limit of stocking for the target stand is approximately 32 m^2/ha. Given a residual stocking of 18 m^2/ha, the stand can therefore recover approximately 14 m^2/ha of basal area before the onset of competition-induced mortality. Using the data cited above from Marshall (unpublished data 1997) for managed stands in Knife Creek, basal area was estimated to grow at a rate of 8.3 m^2/ha per decade. A cutting cycle of 17 years was therefore indicated.

The cutting cycle was set at 20 years to recognize several factors:

- the relatively long cutting cycle will allow some mortality, which is not recognized in Marshall's data;
- average diameter growth ranges between 1.2 and 2.5 cm/decade in Knife Creek in unmanaged stands -- a 20 year re-entry period will allow more trees to pass into the next diameter class between entries;
- reserved basal area for very large trees will grow;
- recruitment of snags and coarse woody debris will be enhanced by a slightly extended cutting cycle; and
- the exposure requirements of interior Douglas-fir indicate that a longer cutting cycle may be beneficial.

Marking

Marking is "...the mechanism that facilitates the regulation of ... partial cutting..." (Anderson and Rice 1993). Marking therefore applies the stand management objectives to the stand as it exists at the present time (Day 1996) -- it is particularly important in the first entry into a stand, because of the large number of stems and wide range of quality and vigour in the unmanaged stand (Fiedler 1995). The residual stand should not be comprised of "left-overs" (Fiedler 1995), so marking should focus on the residual trees.

Marking guides provide a tree classification system to assist qualitative decisions (Anderson and Rice 1993), as well as quantitative guidance for a given stand (Marquis 1976, Guldin 1991). Tree classification interprets management objectives, the silvics of the species, and the ecology of the site. A tree classification for Knife Creek is shown below in Table 1. Marking should select leave trees in the A and B classes, and concentrate harvesting in the C and B classes.

Classification of trees by their vigour is relatively simple, given some experience. Schmidt et al. (1976) provide qualitative criteria for identifying vigourous Douglas-fir, and those descriptions are presented in Table 2 with some modification to localize the criteria to Knife Creek.

Discussion

The mule deer winter range strategy developed under the Cariboo Chilcotin Land Use Plan precludes harvesting from the Knife Creek block, because crown closure ratios are not in the required range. However, uneven-aged Douglas-fir stands have historically been maintained by frequent low-intensity fires. Fires have been absent from the Knife Creek block since 1915 (Daniels et al. 1996) which agrees with changes in fire frequency reported widely in the literature from throughout western North America. There is little doubt that cessation of natural fires has led to increased densities of saplings. Parminter (1978), Kilgore (1981), and Arno (1991) all conclude that reduced fire frequency in uneven-aged forests has resulted in an increase in the density of smaller stems.

The maintenance of stand structures conducive to mule deer winter range is therefore dependent on disturbance. It is the author's opinion that forests which do not have optimum stand structure and crown closure conditions require carefully planned and executed harvesting to improve those conditions. In every stand table examined in the Knife Creek block, there is an excess of stems in small diameters, and a lack of stems in large diameters when compared to the target stand structure described earlier.

Table 1: Tree classification for timber marking on mule deer winter range.

Class	Species	Values	Future
A1	Douglas-fir.	Currently providing good cover and forage.	Good vigour and low risk[5].
A2	Douglas-fir.	Currently providing good cover and forage.	Poor vigour and low risk.
A3	Douglas-fir.	Potentially providing good cover and forage.	Good vigour and low risk.
B1	Any species (including Douglas-fir).	Neither currently nor potentially providing good cover and forage but with good timber potential.	Good vigour and low risk.
B2	Any species (including Douglas-fir).	Neither currently nor potentially providing good cover and forage but with good timber potential.	Poor vigour and low risk.
C	Any species (including Douglas-fir).		Poor vigour and high risk.

Table 2: Vigour classification by qualitative descriptions for interior Douglas-fir (after Schmidt et al. 1976).

Characteristic	Good Vigour	Fair Vigour	Poor Vigour
Crown Class	Dominant or Codominant.	Codominant or Intermediate.	Intermediate or Suppressed.
Live Crown Ratio	> 40%	20 - 40%	< 20%
Crown Shape	Pointed to rounded.	Rounded to flat.	Flat or spike-topped.
Crown and Foliage	Dead branches rare. Foliage moderately dense or better.	Occasional dead branches. Foliage moderately dense.	Dead branches frequent. Foliage thinning to sparse.
Bark	Dark bark plates at base are broad with well exposed new bark between. Upper bole -- ¼ or more of tree height light gray and smooth.	Less exposed new bark between plates. Upper bole -- less than ¼ of tree height light gray and smooth.	No new bark exposed between plates. Upper bole -- dark gray rough bark for entire stem.
Insects or Disease	Free of damage.	Light damage.	Mod. to heavy damage.

[5] Risk is defined as the likelihood of the tree dying before the next entry.

Figure 3 provides an example of a typical diameter distribution for a stand at Knife Creek. Note that the stand is overstocked in diameter classes less than 30 cm, and understocked in larger classes. It is concluded that the best treatment for this stand is to harvest the surplus growing stock in the small sizes, so that the stocking in larger sizes can grow.

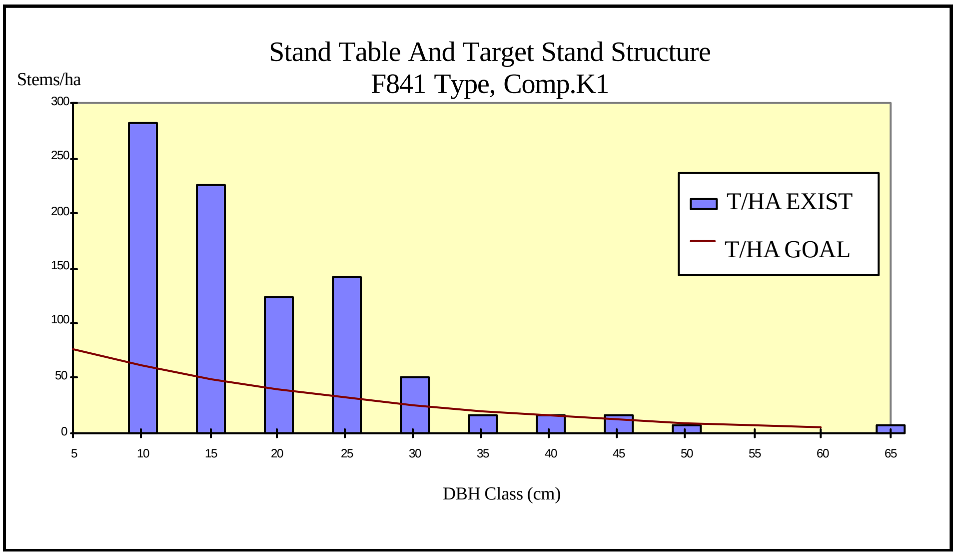

Figure 3: Stand structure of a high-crown-closure stand, compared to the target stand structure.

In the absence of disturbance, the larger trees will die and their space will be taken up by growth and ingress of small stems. Over-stocking will result, which leads to stagnation and poor stand vigour in these dry ecosystems.

The overstocking in the smaller size classes may contribute to the mortality of the larger trees, due to stress imposed through moisture competition (Day 1996). Larsson et al. (1983) suggest that similar conditions in ponderosa pine led to loss of large trees to bark beetles through time. It is possible that these conditions of overstocking have contributed to recent losses caused by Douglas-fir bark beetles (*Dendroctonus psuedotsugae*) in the Williams Lake Forest District. The Mule Deer Winter Range Strategy Committee (1996) cited Douglas-fir bark beetles as a significant threat to mule deer winter ranges in the Cariboo. It is therefore suggested that careful harvesting that reduces stocking in the smaller diameter classes is a proactive approach to reducing losses to Douglas-fir bark beetle and improving stand structure for mule deer.

Low stand vigour, mortality, and overstocking lead to fuel conditions which are conducive to stand replacing fires (Arno 1980; Kilgore 1981; Steele et al. 1986). Stand replacing fires have a role in these ecosystems, but will cause long-term losses of productive mule deer winter range. Maintenance of appropriate stand structures and reduction of accumulated fuels by harvesting will reduce the hazard of catastrophic fires.

Conclusions

Mule deer in the Cariboo are dependent on Douglas-fir forests in particular climatic and topographic conditions to meet their habitat needs in the winter. Uneven-aged management is a tool which can be applied to winter ranges to improve their productivity for mule deer and for timber. Current practise on winter ranges is to allow harvest of low volumes of timber if the crown closure conditions exceed the minimum requirement. The objective of the harvest is to remove some timber while maintaining an uneven-aged stand containing significant numbers of large old trees. Target stand structures have not been developed in succinct silvicultural terms or applied in a systematic or measurable way.

This paper proposes a target stand structure intended to provide habitat requirements for mule deer on the Knife Creek winter range, and offers a tree classification system which will aid in timber marking on mule deer winter range. Cutting cycles of 20 years will maintain stocking within appropriate limits, and maintain target stand structures. Active forest management is required in dry Douglas-fir forests, to replace the natural fire regime that has ceased to function. Failure to proactively manage for winter range carries increased risk of loss from bark beetles and catastrophic fires.

Carefully applied selection management as described in this paper, using appropriately implemented harvesting, can be applied to improve the value of mule deer winter range. The approach will provide harvesting opportunities in areas currently not available for timber harvest, as well as enhancing mule deer habitat.

References Cited

Anderson, H.W. and J.A. Rice. 1993. A tree-marking guide for the tolerant hardwoods working group in Ontario. OMNR Forest Res. Branch. Queens Printer for Ont.

Armleder, H.M., R.J. Dawson, and R.N. Thomson. 1986. Handbook for timber and mule deer management coordination on winter ranges in the Cariboo Forest Region. Land Management Handbook 13. BC Min. For. Res. Branch.

Arno, S.F. 1980. Forest fire history in the northern Rockies. J. For. 78:460-465.

______. 1991. Ecological relationships of interior Douglas-fir. *proc.* Interior Douglas-fir: The species and its management. D.M. Baumgartner and J.E. Lotan (eds.) WSU Dept. Nat. Res. Sci. pp.9-14.

Becker, R. 1995. Operational considerations of implementing uneven-aged management. *proc*. Uneven-aged management: Opportunities, constraints and methodologies. K.L. O'Hara (Ed). Montana For. and Cons. Exp. Sta. Misc. Pub. No. 56.

Chen, H.Y.H., K. Klinka, and G.J. Kayahara. 1995. Effects of light on growth, crown architecture, and specific leaf area for naturally established Pinus contorta and Pseudotsuga menziesii var. glauca saplings. In review.

Daniel, T.W., J.A. Helms, and F.S. Baker. 1979. Principles of silviculture. 2nd Ed. McGraw-Hill New York. 500 pp.

Daniels, L.D., J. Dobry, and K. Klinka. 1995. Fire history of two Douglas-fir stands in the Alex Fraser Research Forest: a pilot study. Unpub. Contract Rept. BC MoF Cariboo Region, Williams Lake.

Davis, L.S. and K.N. Johnson. 1987. Forest Management. 3rd Ed. McGraw Hill, New York.

Day, K. 1996. Interior Douglas-fir and selection management. Unpub. Rept. UBC Faculty of Forestry. 34 pp.

_______. 1997a. Management and working plan #2 (Draft). UBC/Alex Fraser Research Forest. Unpub.

_______. 1997b. Stocking standards for uneven-aged interior Douglas-fir. Unpublished Report, UBC Faculty of Forestry. 29 pp.

Fiedler, C.E. 1995. The basal area-maximum diameter-q (BDq) approach to regulating uneven-aged stands. *proc.* Uneven-aged management: Opportunities, constraints and methodologies. K.L. O'Hara (Ed). Montana For. and Cons. Exp. Sta. Misc. Pub. No. 56.

Geist, V. 1990. Mule deer country. Western Producer Prairie Books, Saskatoon SK.

Ginrich, S.F. 1967. Measuring and evaluating stocking and stand density in upland hardwood forests in the central states. Forest Sci. 13(4):38-53.

Guldin, J.M. 1991. Uneven-aged BDq regulation of Sierra Nevada mixed conifers. WJAF 6(2):27-32.

Hope, G.D., W.R. Mitchell, D.A. Lloyd, W.R. Erickson, W.L. Harper, and B.M. Wikeem. 1991. Interior Douglas-fir Zone. *in* Ecosystems of British Columbia. D. Meidinger and J. Pojar (ed.) B.C. Min. For., Res. Br., Chap. 10, pp. 153-165.

Kilgore, B.M. 1981. Fire in ecosystem distribution and structure: western forests and scrublands. *proc.* Fire Regimes and ecosystem properties. H.A. Mooney, T.lM. Bonnickson, N.L. Christensen, J.E. Lotan, and W.A. Reiners (Coord.) USDA For. Serv. Gen. Tech. Rept. WO-26.

Larsson, S., R. Oren, R.H. Waring, and J.W. Barrett. 1983. Attacks of mountain pine beetle as related to tree vigor of ponderosa pine. Forest Sci. 29:395-402

Leak, W.B. 1976. Stand structure. In Uneven-aged silviculture and management in the United States. USDA For. Ser. Timber Mngmt Branch. Washington, DC

Long, J.N. 1985. A practical approach to density management. For. Chron. 61:23-27.

Marquis, D.A. 1976. Application of uneven-aged silviculture and management on public and private lands. *proc.* Uneven-aged silviculture and management in the United States. . Timber Management Research For. Serv. USDA. Washington.

Marshall, P.L. and Y. Wang. 1996. Growth of uneven-aged interior Douglas-fir stands as influenced by different stand structures. Can. BC Joint Pub. FRDA II Rpt. 267.

Matthews, J.D. 1991. Silvicultural systems. Oxford University Press, N.Y. pp163-173.

Mule Deer Winter Range Strategy Committee. 1996. Regional mule deer winter range strategy for the Cariboo-Chilcotin Land Use Plan. BC Environment, Williams Lake BC.

Nyland, R.D. 1996. Silviculture concepts and applications. McGraw-Hill New York.

Parminter, J.V. 1978. Forest encroachment upon grassland range in the Chilcotin region of British Columbia. Unpub. Masters Thesis. UBC Faculty of Forestry.

Schmidt, W.C., R.C. Shearer, and A.L. Roe. 1976. Ecology and silviculture of western larch forests. USDA For. Serv. Tech. Bull. 1520. 96 pp.

SIWG. 1992. Correlated guidelines for management of uneven-aged drybelt Douglas-fir stands in British Columbia: first approximations. BC Min. For. Silv. Br.

Steele, R. , S.F. Arno, and K. Geier-Hayes. 1986. Wildfire patterns change in central Idaho's ponderosa pine-Douglas-fir forests. West. Journal Appl. For. 1:16-18.