ENHANCING BIODIVERSITY THROUGH

PARTIAL CUTTING

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EXECUTIVE SUMMARY

This project was initiated by the BC Ministry of Forests (Forest Practices Branch) to evaluate partial cutting opportunities in areas set aside for the management of biodiversity. Areas, forest types and circumstances where partial cutting would potentially enhance forest habitat under operationally and economically feasible conditions were identified by (i) gathering information on biodiversity objectives, management and applications of partial cutting methods and (ii) conducting focused analyses of five distinct units in the Nelson Forest Region. These analysis units, which are described in the report's appendix, include:

1. Enhanced Forest Management Pilot Project Area (Invermere Forest District);
2. West Arm Demonstration Forest (Kootenay Lake Forest District);
3. Stagleap Landscape Unit (Arrow Forest District);
4. Kalesnikoff Lumber Co. Operating Area (Arrow and Kootenay Lake Forest Districts); and
5. High Biodiversity Emphasis Areas in Landscape Units B1, B2, and B3 (Boundary Forest District).

Types of set aside areas for biodiversity found in the southern interior of British Columbia and considered in this report include the following:

- Old-growth Management Areas;
- Riparian Management Areas;
- Lakeshore Management Areas;
- Ungulate Winter Ranges;
- Caribou Special Management Zones;
- Wildlife Habitat Areas for Identified Species (Northern Goshawk);
- Avalanche Track Management Areas; and
- High Biodiversity Emphasis Areas in fire-maintained (NDT4) ecosystems.

For each type of biodiversity management area, current provincial management directions, stand structural targets, and partial cutting considerations were reviewed and pertinent examples were provided to focus the analysis. Overall, partial cutting appears to be an appropriate management tool for meeting specific biodiversity objectives and the following circumstances are most likely to benefit from partial cutting:

- dry, fire-maintained ecosystems requiring restoration;
- mature stands appropriate for old-growth recruitment;
- mature and young stands devoid of veteran trees and other stand structural legacies; and
- stands threatened by disease or insect outbreaks.

Areas where partial cutting would have less impact on biodiversity than clearcutting include:

- riparian, lakeshore, and avalanche track management areas;
- caribou special management zones; and
- Northern Goshawk wildlife habitat areas.

No harvesting should occur in riparian, lakeshore and old-growth reserves.

Potential partial cutting prescriptions must reflect site-specific conditions and few generalizations are possible due to the high variability in ecological parameters. The use of partial cutting prescriptions to meet biodiversity objectives has not been operationally tested and requires an adaptive management approach. Prescriptions should therefore be (i) developed cautiously, (ii) implemented using experienced personnel and well-supervised logging operations, and followed up with (iii) rigorous and systematic post-treatment monitoring. Although ungulate habitat enhancement trials using partial cutting have been conducted throughout British Columbia, monitoring associated with these trials is often inadequate or short term.

Douglas-fir-, western larch- and ponderosa pine-leading stands are most suitable for partial cutting because of their windfirmness, regeneration potential, and stand composition and structural characteristics. Lodgepole pine-leading stands have intermediate suitability for partial cutting, while hemlock-leading

stands are least suitable. However, there is consensus that given the right stand and market conditions, partial cutting is feasible in most forest types.

Selection of particular partial cutting systems (e.g., single tree versus group selection) depends on site-specific factors. If minimal impact on structural attributes throughout a stand is desirable (e.g., in riparian management zones, wildlife habitat areas, or old-growth recruitment stands), single tree selection is generally most suitable. If forest gaps and other small openings are included as stand structural targets (e.g., in ungulate winter range or caribou habitat), group selection cuts are more suitable than single tree selection. Group selection cuts may also be preferable in stands at climatic extremes (e.g., dry open IDF subject to moisture stress or high elevation ESSF with high snow press) because they mimic the forest gaps, small openings and clumped tree distributions characteristic of these stands.

Economic opportunities from partial cutting obviously depend on a multitude of factors, some of which are variable in time (e.g., market prices for timber), however some generalizations are possible. Partial cutting in areas set aside for biodiversity will primarily generate small sawlogs that are lower in value compared with regular sawlogs and peeler logs. The most economical harvesting methods are ground-based, cable and horse logging, in that order. Under favorable conditions, all of these methods may be feasible.

Broad scale application of partial cutting systems will necessitate linkages with higher level planning, landscape unit objectives, landscape uses other than forestry, and ecological parameters such as connectivity, patch size, interior habitat, and abundance and distribution of stand structural features throughout the landscape.

Summaries of the five focal analysis units are as follows:

Enhanced Forest Management Pilot Project Area (Invermere Forest District) - Partial cutting is an integral component of the pilot project. Opportunities to enhance biodiversity through partial cutting exist within (i) the 15,773 ha of NDT4 ecosystems (to reduce forest ingrowth in open forests and forest encroachment in open range, and to prepare stands for periodic burning), (ii) the 15,989 ha of Forest Ecosystem Networks primarily where old-growth restoration and recruitment is desirable or where forest health cuts are required to prevent major insect outbreaks, and (iii) ungulate winter ranges to improve growth of forage species or to promote canopy cover. Partial cutting opportunities potentially also exist within Northern Goshawk "wildlife habitat areas" and recommendations for the development of case studies are provided in Appendix 1.

West Arm Demonstration Forest (Kootenay Lake Forest District) - Maintenance of biodiversity at stand and landscape levels is a primary management goal in the West Arm Demonstration Forest. Partial cutting opportunities exist in (i) ungulate winter ranges on relatively dry ICHdw and ICHmw2 sites subject to high snowfall and (ii) in multi-layered Douglas-fir-leading ICHdw stands for old-growth recruitment (this variant is deficient in age class 8 and 9). Silviculture prescription recommendations for old-growth recruitment are provided in Appendix 2. Limited potential for single tree or group selection cuts exist within riparian management areas where forest health problems severely limit habitat connectivity.

Stagleap Landscape Unit (Arrow Forest District) - The Caribou Special Management Zone within the Stagleap landscape unit is intended to supply core habitat for the blue-listed Selkirk herd of mountain caribou. The area covers 30,421 ha, of which 28% lies within the operable forest landbase). Areas currently used by caribou are not considered suitable for partial cutting, however habitat recruitment appears to be feasible in areas where patches of core habitat are separated by stands of low habitat value (i.e., low crown closure and lichen loading). Silviculture prescription recommendations and other forest management considerations for a caribou habitat recruitment case study are given in Appendix 3.

Kalesnikoff Lumber Co. Operating Area (Arrow and Kootenay Lake Forest Districts) - Partial cutting is commonly applied in the Kalesnikoff operating area to satisfy ungulate winter range and forest health objectives. Partial cutting opportunities exist in old-growth recruitment areas (age class 7 or younger), fire-maintained (NDT4) ecosystems, ungulate winter ranges and riparian management zones. Partial cutting may also be feasible in Northern Goshawk breeding territories and Avalanche Track Management Zones. General recommendations for the development of a partial cutting (single tree selection) case study in a Riparian Management Zone are provided in Appendix 4. Objectives include: (i) harvest of high-value wood products (e.g., cedar poles) and (ii) removal of western white pine infected with blister rust.

Boundary Forest District NDT4 High Biodiversity Emphasis Areas - A total of 15,850 ha (or 61% of NDT4 forests contributing to the Annual Allowable Cut) is to be maintained as old-seral forest (9,933 ha existing and 5,917 ha recruited). This area entirely covers the open and managed forest ecosystem components within the IDF biogeoclimatic zone of Rock, Gilpin and Lynch landscape units. Partial cutting is necessary in these areas to (i) arrive at the desirable distribution and stand structure of the managed forest, open forest and open range ecosystem components and (ii) meet old-seral targets recommended in the FPC *Biodiversity Guidebook*. Focus should be on removal of small and medium-sized trees and retention of large old and valuable wildlife trees, coupled with post-harvest burning wherever possible. Appendix 5 provides a case study description for NDT4 ecosystem restoration and old-growth recruitment.

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1.0 INTRODUCTION

The structure and ecological function of forests in British Columbia are influenced by a range forest management activities (e.g., wildfire suppression, forest harvesting and silviculture). Potentially negative impacts of these activities on wildlife and general biological diversity (biodiversity) have been acknowledged and mitigation efforts have been formulated in, for example, the Forest Practices Code (FPC) *Biodiversity Guidebook* (Province of British Columbia 1995a). One approach to maintaining components of biodiversity is to reserve or otherwise set aside areas where forestry activities are excluded or constrained (e.g., riparian reserves, caribou management areas, old-growth management areas). However, the structure and ecological function of such areas cannot be considered pristine as they are affected by forestry and other human activities in the surrounding landscape; even protected stands may be too densely stocked, composed of unnatural tree species composition, or ecologically unhealthy. The question therefore arises: are there areas where partial cutting of stands would facilitate meeting biodiversity objectives? To answer this question and to evaluate the economic feasibility of potential partial cutting opportunities, the Forest Practices Branch of the BC Ministry of Forests initiated this project, with funding from Forest Renewal BC.

The specific objectives of this project are to:

1. identify forest types that offer opportunities for achieving or enhancing biodiversity objectives through partial cutting;

2. determine the most appropriate partial cutting methods for candidate forest types and evaluate their economic feasibility; and

3. provide a landscape management context for areas where partial cutting may be feasible to meet biodiversity objectives.

This project is a sequel to a previous project titled "Evaluating the available merchantable volume for harvesting if alternative silvicultural systems were used on wildlife and biodiversity set-aside areas" (Simons Reid Collins 1998). While the primary goal of the Simons Reid Collins project was to evaluate opportunities for incremental fibre production in areas set aside for biodiversity, this project focuses on forest stands where timber removal through partial cutting is either necessary or beneficial to achieve biodiversity objectives. The approach taken involves (i) information gathering on biodiversity objectives and management and on applications of partial cutting methods and (ii) focused analyses of five distinct analysis units in the Nelson Forest Region. These analysis units, which are described in the report's appendix, include:

1. Enhanced Forest Management Pilot Project Area (Invermere Forest District);

2. West Arm Demonstration Forest (Kootenay Lake Forest District);

3. Stagleap Landscape Unit (Arrow Forest District);

4. Kalesnikoff Lumber Co. Operating Area (Arrow and Kootenay Lake Forest Districts); and

5. High Biodiversity Emphasis Areas in Landscape Units B1, B2, and B3 (Boundary Forest District).

Since well-documented quantitative information to evaluate the risks and benefits of applying partial cutting systems to meet biodiversity objectives are limited, a concerted effort was made to include the professional judgements of as wide a variety of experts from the fields of biology and forest management as possible (see Acknowledgements).

This project focuses on relatively dry ecosystems (natural disturbance types [NDT] 2, 3, and 4; Province of British Columbia 1995a) within the Interior Douglas-fir (IDF), Interior Cedar–Hemlock (ICH), Montane Spruce (MS) and Engelmann Spruce–Subalpine Fir (ESSF) biogeoclimatic zones (Braumandl and Curran 1992) of the Nelson Forest Region. Within these ecosystems, opportunities for partial harvesting are identified by formulating benchmarks for stand structure (e.g., number of canopy layers, stem densities, crown closure, or presence of gaps) and associated attributes (e.g., snags, trees with large crowns, diseased or defective trees).

Our evaluation of the suitability of partial cutting for biodiversity management is based on three general assumptions that reflect both ecological principles and current resource management directives in B.C.:

1. Partial cutting potentially enhances stand structure and composition for biodiversity objectives.

2. Partial cutting (as an alternative to clearcutting) may promote biodiversity objectives.

3. Partial cutting (as an alternative to no cutting) may facilitate meeting the maximum annual allowable cut (AAC) impact targets set by the Province for biodiversity management (e.g., the maximum AAC impact for the FPC *Identified Wildlife Management Strategy* is 1%; Province of British Columbia 1999b)[1].

This project was undertaken prior to the finalization of the FPC *Landscape Unit Planning Guide* (Province of British Columbia 1999a), which addresses two of the six biodiversity elements listed in the Strategic Planning regulations. Although this project takes a broader approach to biodiversity management than the LUPG, results presented here complement the guide and attempt to explore alternatives that may assist with the development of adaptive management approaches.

2.0 METHODOLOGY

Terms and Definitions

'Analysis Unit' - A distinct forest management area selected for this project on the basis of constrained areas and available background information (see Appendix).

'Biodiversity' - The diversity of plants, animals and other living organisms in all their forms and levels of organization, and includes the diversity of genes, species and ecosystems, as well as the evolutionary and functional processes that link them (Province of British Columbia 1995a). Wildlife is a subset of biodiversity.

'Partial cutting' - For this project, defined as a silvicultural system in which only selected trees are harvested and includes shelterwood, single tree, group selection, and patch cutting (i.e., openings that are < 1 ha in size).

'Constrained or set-aside area' - Included are all operable forested areas where timber production (as a primary objective) is constrained due to biodiversity or specific wildlife habitat objectives.

Literature Review and Information Sources

For each type of wildlife or biodiversity management area considered, current provincial management direction, available stand structural targets and partial cutting considerations were reviewed and pertinent partial cutting studies were described. Literature cited includes published scientific articles and agency reports, as well as case studies and operational trials currently underway in B.C. Information pertaining to ongoing or unpublished reports was found on the World Wide Web and through personal communication with district offices. In addition, opinions of many experts in the various fields were canvassed to synthesize existing knowledge or highlight areas of contention amongst practitioners. The latter included a half-day workshop held in February 1999 at the Ministry of Environment Office in Nelson.

[1] If harvesting is to be excluded or minimized in some Wildlife Habitat Areas (WHAs), partial cutting with low retention levels or clearcutting will have to occur in non-WHAs to stay within the 1% maximum allowable AAC impact target. Alternatively, if ecologically–sound partial cutting with high retention levels is applied in suitable WHAs, a larger total number of WHAs may be designated within the fixed impact target. However, the ecological soundness of partial cutting needs to be established on a site-specific basis.

Analysis Units

Analysis units for this project were selected on the basis of (i) abundance and variety of set-aside areas (within and among units) and (ii) available background information on ecological parameters, bioterrain features, and forest inventory. A brief rationale for the selection of each analysis unit follows and detailed descriptions of each are provided in the appendices. In combination, these management units represent an area of approximately 380,000 ha.

1. Enhanced Forest Management Pilot Project Area (Invermere Forest District)
Since 1996, a variety of forest inventory and research activities have been underway in the approximately 260,000 ha pilot area, which includes an extensive forest ecosystem network and other constrained areas. These initiatives (re)examine the effects of various harvesting systems on a variety of resources values, and include research on biodiversity components in relation to partial cutting systems. A series of project summaries and interim reports are available from the Invermere Forest District on topics that include the project overview (Anderson 1997), ecosystem restoration (White 1997), commercial thinning (Stone and Mitchell 1997), East Kootenay songbird project (Stuart–Smith 1998), partial cutting in old-growth stands (Steeger and Quesnel 1998) and Northern Goshawk habitat requirements (Machmer et al. 1999).

2. West Arm Demonstration Forest (Kootenay Lake Forest District)
The West Arm Demonstration Forest is a 13,500 ha area managed by the Forest Service east of Nelson, B.C. Its objectives are to demonstrate new and innovative silvicultural systems which satisfy a variety of stand and landscape level goals, provide a location for long-term research projects (including hydrologic and wildlife studies) and explore improved methods of public participation. A number of initiatives explicitly seek to demonstrate appropriate harvesting in areas constrained by wildlife, water, visual, recreation and old-growth values (Working Committee, West Arm Demonstration Forest Strategic Plan 1998).

3. Caribou Special Management Zone - Stagleap Landscape Unit (Arrow Forest District)
Caribou special management zones constrain timber availability in some landscape units of the Nelson Forest Region. The southern-Selkirk caribou herd inhabits the high-elevation ecosystem of the Stagleap landscape unit and areas across the international border in Washington and Idaho. In Canada, the SMZ is approximately 30,000 ha in size. Research and operational trials on partial cutting systems to enhance caribou habitat were initiated 15 years ago (D. DeLong, pers. comm.) and post-treatment information on the development of treated stands was recently collected to determine how well initial trials met objectives.

4. Kalesnikoff Lumber Co. Operating Area (Arrow and Kootenay Lake Forest Districts)
The Kalesnikoff Lumber Co. operating area encompasses 50,000 ha, of which approximately one third is operable. Within the latter, several biodiversity set-aside areas exist. Kalesnikoff has considerable experience in partial harvesting and selection silvicultural practices constituted 65% of its' 1995 harvesting operations. The company focuses on value-added and speciality wood products, which enhances the economic feasibility of partial cutting.

5. NDT4 High Biodiversity Emphasis Area (Boundary Forest District)
Approximately 26,000 ha of contributing IDF forest within the Rock, Gilpin, and Lynch landscape units is to be managed under the high biodiversity emphasis option (Kootenay Inter-Agency Management Committee 1997). Fire-maintained ecosystem (NDT4) restoration and old-growth recruitment are primary management objectives and many stands need to be partially harvested to achieve biodiversity objectives. Management guidelines with specific quantitative prescriptions have been developed for this area by Steeger and Hawe (1998) and general NDT4 management guidelines are currently being developed by the Boundary Forest District (Jeff Leahy, pers. comm.) and Pope & Talbot Ltd. (Jim Graham, pers. comm.). Ungulate winter ranges overlap considerably with the NDT4 high biodiversity area and efforts are underway to develop ungulate winter range guidelines that are integrated with other ecosystem management objectives (Rick Heinrich, pers.comm.).

Analysis of Partial Cutting Opportunities

Evaluation of each of the five analysis units involved the following steps (in the appendices, each step and analysis unit correspond to one table and appendix, respectively).

Step 1: Description of management unit (i.e., location, area, ecosystems, resource management plans and pertinent issues);

Step 2: Description of areas set aside for biodiversity (i.e, type, total area, ecosystems, and comments on stand composition and structural targets). Included are quantitative targets specific to the analysis unit if available (e.g., forest cover in ungulate winter range, basal area in riparian management areas, or stem densities in NDT4 ecosystem components);

Step 3: Decision and rationale for partial cutting suitability of set-aside areas, based on biodiversity objectives, forest types, stand structure targets, and risks or benefits of using various partial cutting systems; and

Step 4: Descriptions of partial cutting case studies for suitable set-aside areas (included are ecological and management background information, silviculture prescription recommendations and an economic evaluation of the proposed trials).

Methods for Economic Analysis

The economic evaluation examines primary variables which affect cost of production and compares these to market price thresholds to determine the economic viability of various silvicultural systems and harvesting methods. The cost variables include average efficient production rates for three common stump to truck partial cutting methods, average layout/engineering costs, hauling costs and stumpage. Log market prices relate to the average price of logs produced from a cutblock including a variety of species and piece sizes (primary value criteria). The economic viability of a cutblock can be estimated by using a simple matrix and comparing the major cost factors against three different average market prices.

3.0 THE ROLE OF PARTIAL CUTTING IN BIODIVERSITY MANAGEMENT: A LITERATURE REVIEW

Partial cutting has the potential to reduce short and long-term timber supply impacts by minimizing constraints associated with adjacency rules, thereby increasing timber availability in areas otherwise constrained by non-timber resource objectives (Hawe 1996). To assess this potential in forest districts of the Nelson Region, Hawe (1996) conducted a review of silvicultural systems used by the Small Business Forest Enterprise Program (SBFEP) and major licensees since 1986. Different patterns of silvicultural systems use were observed across the seven districts (Table 1). Three districts (Golden, Revelstoke and Kootenay Lake) hardly use partial cutting (80–100% of the harvested areas were clearcut) and the remaining four (Boundary, Cranbrook, Invermere and Arrow) used a variety of silvicultural systems (Table 1), with relatively limited use of high volume retention systems. Although the patterns of silvicultural systems used are linked to the types of timber present in each district, Hawe reports that even within a timber type, districts used different silviculture systems and attempting to infer suitability of silvicultural systems to different timber types from these data is therefore difficult. The author concludes that use of low retention systems (i.e., seedtree and shelterwood) did little to mitigate adjacency constraints and that increased use of high retention systems have considerable potential to mitigate timber supply shortages and increase value to biodiversity in all districts (Hawe 1996).

Table 1. Percentage of total area in different silvicultural systems, Nelson Forest Region, 1988-1996 (from Hawe 1996).

District	Tenure holder	Silviculture System (% of total area harvested)				
		Clearcut	Seedtree	Group Selection	Single-tree Selection	Shelter-wood
Cranbrook	SBFEP	20	8	5	43	3
	Licensee	48	3	6	2	4
Boundary	SBFEP	32	39	1	26	1
	Licensee	46	46	4	2	<1
Invermere	SBFEP	37	27	1	17	18
	Licensee	59	20	3	7	11
Arrow	SBFEP	41	8	5	43	3
	Licensee	85	3	6	2	4
Kootenay Lake	SBFEP	81	11	-	8	<1
	Licensee	83	10	2	2	1
Golden	SBFEP	90	3	-	6	-
	Licensee	95	2	2	<1	-
Revelstoke	SBFEP	100	-	-	-	-
	Licensee	97	-	-	3	-

In a corollary to Hawe's 1996 study, Listar (1998) used a stand growth and yield model (PROGNOSIS) to examine the impact of stand and silvicultural system parameters on stand productivity (mean annual increment, MAI). The study identifies timber types in which partial cutting can be used with low risk, based on the following criteria: (i) biologically suitable, (ii) high probability of regeneration success and (iii) minimizing the negative effects of *Armillaria* and other forest pathogens (Listar 1998). The results demonstrate how MAI is optimized in different stand types, dependent on the combination of *Armillaria* levels and scheduling parameters (note that scenarios are relative rather than absolute, since the model is not yet calibrated for British Columbia). The highest MAI was achieved when partial cutting younger stands (Listar 1998), which supports the concept of commercial thinning or wind-firming younger stands to increase the production of larger trees. However, some combinations of residual basal area and timing of harvest significantly reduced MAIs compared with clearcutting,. Although not necessarily relevant to this study (which focuses on maintaining biodiversity, rather than maximizing timber), the report does identify the potential for decreased long-term timber productivity if partial cutting is used inappropriately. Listar (1998) concludes that short and long-term timber shortages can be mitigated by using "a more balanced mixture of clearcutting and partial cutting silviculture systems…". Reduced growth of a stand after partial cutting could result in decreased value from a biodiveristy as well as timber perspective. The latter assumption is based on the fact that limits to biodiversity are often determined by large-sized structural attributes (i.e., standing dead or live trees, or coarse woody debris). Partial cutting for biodiversity objectives should therefore at least consider the results presented by Listar.

3.1 Objectives and management of areas set aside for biodiversity in the southern interior of British Columbia

The following types of areas set aside for biodiversity in the southern interior of British Columbia are considered in this literature review and the following analyses:

- Old-growth Management Areas;
- Riparian Management Areas;
- Lakeshore Management Areas;
- Ungulate Winter Range;
- Caribou Special Management Zones;
- Wildlife Habitat Areas for Identified Species (Northern Goshawk);
- Avalanche Track Management Areas; and
- High Biodiversity Emphasis Areas in NDT4 ecosystems.

Current provincial management direction[1], stand structural targets, and partial cutting considerations for each topic are reviewed with pertinent examples to focus the analysis.

3.1.1 Old-growth Management Areas and Recruitment Old-growth

Provincial Management Direction

The Province of British Columbia (1995a) defines old-growth as forest stands >140 (age class 8) or >250 (age class 9) years, depending on biogeoclimatic ecosystem classification (BEC) zone. In order to maintain representative old-growth ecosystems across the landscape, the FPC *Landscape Unit Planning Guide* (Province of British Columbia 1999a) in concert with the FPC *Biodiversity Guidebook* (Province of British Columbia 1995a) recommends retention, by landscape unit, of a percentage of each BEC zone in old-seral forest conditions as Old-Growth Management Areas (OGMAs). The target value is determined by the BEC natural disturbance type (NDT) and the Biodiversity Emphasis Option (BEO = low, intermediate or high). The percentage of a landscape unit designated as old-growth ranges from 2.3 to 28% (low BEO NDT 3 "drawn-down" units versus high BEO NDT 1 landscape units, respectively; Table 2).

Table 2. Percentage of landscape recommended for management in old-seral stage (Province of British Columbia 1995a).

NDT[1]	BEO[2]	Percentage old[3]	Percentage with drawdown[4]
NDT1	L	>13 - >19	>4.3 - >6.3
	I	>13 - >19	
	H	>19 - >28	
NDT2	L	>9	>3
	I	>9	
	H	>13	
NDT3	L	>7 - >14	>2.3 - >4.6
	I	>7 - >14	
	H	>10 - >21	
NDT4	L	>13	>4.3
	I	>13	
	H	>19	

[1] NDT- Natural Disturbance Types (Province of British Columbia 1995a)
[2] Biodiversity Emphasis Option – low, intermediate, high. Landscape units are designated a BEO with 45% of landscape units as low and intermediate, respectively, and 10% as high.
[3] Percentage of each landscape unit, by BEC, recommended for management in old-seral stage (for some NDT types, the target values differ by BEC).
[4] Drawdown – targets for low BEO can be drawn down to one third of the original target, unless it is shown *a priori* that meeting the full target will not impact timber supply. The full target must be met within 3 rotations (approximately 240 years).

In landscape unit where seral targets cannot be met, due to a shortage of old-seral stands, younger stands may be considered for recruitment of old-seral structures. "Recruitment old-growth" is a forest stand targeted to provide future old-seral forest and which may or may not currently contain old-growth attributes. Recruitment old-growth is identified in the Kootenay Region as the oldest available forest since this will presumably become old-growth in the shortest possible timeframe (Kootenay Inter-Agency Management Committee 1997).

The FPC Landscape Unit Planning Guide (Province of British Columbia 1999a) states that forest in the non-contributing landbase must be designated to meet old-seral targets before old-seral forest from within the Timber Harvesting Land Base (THLB) may be considered for retention. To maximize benefits to old-seral habitat and to provide interior forest conditions, large patches of old forest should be designated to meet old-seral targets where they exist (Steeger et al. 1997; Holt and Steeger 1998). However, a deficit of old-seral stands will result in some younger seral forest being included in OGMAs. This same principle

[1] Included are laws, policies, regulations, standards, guidelines, mandatory requirements and memoranda of understanding. We also considered higher level plans and special management plans currently being implemented.

may also be applied were the old-seral occurs in many small scattered patches. In these areas, surrounding old-growth with younger recruitment forest will buffer the existing old-growth from external impacts (e.g., adjacent logging) and provide for larger old-seral patches in the future. Recruitment old-growth may therefore be designated either as discrete patches or as areas surrounding existing old-growth stands.

Stand structural targets

It is widely acknowledged that stand structural attributes better define the functionality of old-seral forests than age classes based on forest cover inventory (Oliver and Larson 1990; Franklin and Spies 1991; Quesnel 1996). The Forest Land Use Liaison Committee's (1989) definition for old-growth focuses on structural uniqueness and concedes that mid-seral forest may, to some extent, function as old–seral forest providing it contains the appropriate structural characteristics (the latter differ by forest type). One feature common to all old-seral definitions is the variation in parameters at all spatial scales (Franklin and Spies 1991; Spies and Franklin 1991; Quesnel 1996; Wells et al. 1998). Variability is an integral part of old-seral forests and must be explicitly included in any strategy attempting to maintain or 'grow' old-seral forest in the landscape.

The importance of old-seral forest for maintaining landscape-level biodiversity has been recognised only relatively recently (Franklin et al. 1981). From a genetic perspective, old-seral forest represents the culmination of a long period of competition combined with the ability to withstand natural disturbance events, resulting in a gene pool that differs from that in an adjacent younger stand (Oliver and Larson 1990). Old-seral forest is also important for maintaining populations of "old-growth dependent" species across the landscape (Carey 1989; Ruggiero et al. 1991; MacKinnon 1998). The high and often exclusive biodiversity associated with old-seral forest is thought to arise from a number of factors:

1. High structural diversity and variability. Lists of structural attributes associated with old-growth have been compiled by numerous authors (Franklin et al. 1981; Ruggiero et al. 1991; Holt and Steeger 1998; Steeger and Hawe 1998; Holt and Braumandl 1999) and include presence of relatively large-sized trees, variation in tree sizes, presence of veteran trees and large-sized snags, presence of trees with broken tops, large-sized coarse woody debris, single tree removal gaps, and certain soil types and microsite topography. Preliminary definitions for individual BEC zones are being formulated through intensive research (Kneeshaw and Burton 1998; Holt and Braumandl 1999). All authors note the high inherent variability in key attributes.

2. Typical plant species compositions are often associated with old-seral forest. Note that species richness may be similar between young and old forest, but species composition differs, resulting in different biodiversity values (Halpern and Spies 1995).

3. *Time*. The absolute age of an old-growth forest increases the probability of colonization by poorly mobile species, particularly some plant and lichen species (Goward 1994). Our inability to effectively mimic time through management will ultimately limit our ability to manage a mature stand to produce old-growth.

Partial cutting considerations

Partial harvesting has been suggested as a means by which development of specific old-growth attributes can be accelerated in mature stands. Encouraging the transition from mid to late-seral forest (where the latter is in deficit) is considered beneficial to biodiversity because mid-seral forests tend to have lower biodiversity compared with early and late seral forests (Franklin and Spies 1991).

To our knowledge, no attempts have ever been made to recruit old-seral attributes from younger stands, while wholly maintaining or enhancing the old-growth function of the stand through time (i.e., by not returning the stand to a younger seral stage before regeneration of the stand occurs). The majority of field trials retain old-growth attributes using partial cutting, but are primarily intended as alternatives to clearcutting. This approach will result in more naturally functioning forests in a shorter time-frame than would happen with clearcutting; however, it is fundamentally different from enhancing biodiversity in a mature stand which would otherwise be left to acquire old-growth attributes naturally.

Many of the theoretical and operational case studies addressing old-seral recruitment occur in areas with little or no natural old-growth remaining (Acker et al. 1998; D.K. Coates pers. comm; A. Carey pers. comm.; S. Chan pers. comm.; F. Swanson pers. comm). Management strategies involve (i) reserving all remaining old-growth and (ii) logging second-growth forests while retaining all old-growth structures in order to promote stands which can function as old-growth in the shortest timeframe (Carey et al. 1996). In the interior of British Columbia, a different situation often exists. Although areas may have a deficit of 'old' seral forest according to the FPC *Biodiversity Guidebook* (Province of British Columbia 1995a), there is often an abundance of age class 6 or 7 stands (>100 years), which would relatively rapidly succeed into an old-growth stage in the absence of natural disturbance. The potential benefits and risks to biodiversity associated with manipulating stands thus have to be weighed against simply 'waiting' for time to result in old-growth forest. Theoretically then, we suggest that younger stands are more suitable for old-growth recruitment trials to increase the potential benefits (in terms of 'time gained') and reduce potential costs (for example, impacting an 'almost' old-growth stand) to biodiversity. Three theoretical scenarios illustrate opportunities for old-growth attribute enhancement:

- where age class 9 stands (>250 years) are the target group for old-growth (e.g., NDT 1, 2 and 4) and there is a deficit of age class 8 or older;
- where age class 8 (>140 year) stands are the target age group for old-growth (e.g., NDT3) and where there is a deficit of age class 6 and 7 stands; and
- where second-growth forests are predominant in the landscape (by BEC zone) and where stand structural attributes can be improved.

The key to old-growth recruitment is to determine how many and which trees can be removed while retaining mature and old-seral forest functions. A number of studies have addressed the impacts of partial harvesting on some portion of the flora or fauna of old-growth stands (Steeger et al. 1997; Quesnel et al. 1999; Coates et al. 1998**;** Steventon et al. 1998). These studies provide forest management guidance for their particular target species or guilds, some of which may be considered indicators of important parts of old forest functionality. For example, preliminary results from a series of partial harvest treatments in old-growth of the Interior Douglas-fir ecosystem (IDFdm2) of the Rocky Mountain Trench demonstrate that densities of breeding cavity nesters do not appear to be negatively effected by the treatments (30% and 60% basal area removal) in the short term when essential habitat attributes such as nest trees are protected (Steeger and Quesnel 1998, Quesnel et al. 1999). Note however that in this study retention of existing and potential nest trees was based on the results of pre-harvest surveys for active nest trees and intentionally included in the prescriptions. Hence, these preliminary results primarily indicate that retention of important stand structural attributes and associated ecological processes is possible when made the focus of a prescription. Conversely, partial cutting prescriptions which retain a certain amount of basal area but remove the larger size classes and/or all snags and defective trees are unlikely to maintain old-seral ecosystem function.

Many studies have indirectly addressed issues relating to old-growth recruitment. Below are selected examples which focus on different aspects of old-growth recruitment:

Example 1: Canopy gaps

Ecological patterns and processes in many old-growth ecosystems are linked to the creation of canopy gaps and gap dynamics, resulting from small-scale forest disturbances. Partial cutting systems are also small-scale forest disturbances and knowledge of gap dynamics should facilitate prescription development (Coates and Burton 1997). From a literature review and retrospective analysis of partial harvesting, Coates and Burton conclude that gap size and position within gaps have considerable impact on both microclimate and biological processes. They quantify gap size distribution within stands and use this to describe the internal heterogeneity of the stand to infer suitable partial cutting patterns (Coates and Burton 1997).

Regeneration of species in gaps is also relevant to partial cutting since it will modify re-growth after harvesting. The growth rates of five species (western hemlock, sub-alpine fir, lodgepole pine, western redcedar and spruce) in gaps ranging from single-tree to 5000m^2 were compared in the Interior Cedar Hemlock forest at Date Creek (see Coates et al. 1998 for site description). Growth of all species increased wih gap size to an asymptote at approximately 1000m^2. Growth rates were also similar among all species for small- (20-300m^2) and medium-sized (300-1000m^2) gaps, which encompasses the range of sizes found in small-scale natural disturbances across a range of ecosystems. Mortality rates varied among species in different light conditions, with highest mortality rates on shade-intolerant species in small gaps and in shady portions of medium-sized gaps. Tree position within gaps did not impact growth rates of hemlock and sub-alpine fir, but did impact lodgepole pine, spruce and western redcedar. The latter grew faster in central positions within small and medium-sized gaps than at either the north or south edges. The authors conclude that variable density retention should be favored over even-retention (i.e., even shelterwoods, seed-tree and single-tree selection) in order to maximize re-growth rates of understorey trees (Coates pers. comm.). Matching tree species to position within gaps will also minimize mortality and opening sizes of 0.1 – 0.2 ha can result in maximum tree growth for most of the species studied.

Example 2: Forest development patterns

Patterns of stand development may determine the resulting forest type, and vise versa. Growth rates and resulting diameters of naturally occurring old-growth and younger 'managed' stands in Douglas- fir ecosystems of the Pacific Northwest were compared (Tappeiner et al. 1997). Growth rates and diameters and heights of trees over the first 100 years of existence were found to be much greater in old-growth stands than those in mid-seral stands re-growing after logging. These differences may be explained by the different stand development patterns followed by naturally regenerating versus managed stands. Tappeiner and colleagues suggest that current old-growth stands developed in the last few hundred years without a typical competitive exclusion or "self-thinning" phase (Oliver and Larson 1990; Agee 1991) because the overall density of the stands were generally below that at which self-thinning would occur. They suggest that the observed canopy gaps resulted from irregular and low rates of conifer establishment, in combination with the death of individual large trees. This study has important management implications, raising the question of how long it will take managed stands (initiated at high densities) to reach true old-growth status. They suggest that if 'old-growth' structure is the management objective, thinning during the competitive exclusion phase will allow more rapid growth and promote natural conifer regeneration in the understorey (Bailey 1996), providing an old-seral stand in a shorter time period than would occur naturally. The findings of Tappeiner and colleagues are most relevant to NDT1 and NDT2 ecosystems which naturally experience relatively low frequencies of large-scale disturbances.

Example 3: The Northern Spotted Owl

The Northern Spotted Owl (*Strix occidentalis*) has nest site requirements associated with older-seral unmanaged forests (Forsmann et al. 1984; Forsmann and Meslow 1985). The term 'older forest' is used to distinguish between actual old-growth and forests with structural attributes usually associated with old-growth. Spotted owl habitat in the Pacific Northwest has been dramatically reduced in the last 100 years, resulting in this species' inclusion on the US Endangered Species list. To mitigate loss and enhance suitable habitat, habitat conservation plans have been written for a number of northwest states (e.g., by the Oregon Department of Forestry, T. Haswell, pers. comm.). Habitat enhancement for this species involves production of 'old-growth' attributes (Thomas et al. 1990) in younger seral or second-growth stands. Recommendations promote silvicultural techniques to accelerate the development of spotted owl nesting, roosting, and foraging habitat using measures such as reforestation, thinning, laminated root rot control, green tree retention, snag and down wood retention and creation, group selection of mature trees, creation of multi-layered forest canopies, diverse herb and shrub layers and implementation plans. Measures are implemented as part of an adaptive management approach with monitoring of treatment impacts required. Despite these measures, there remains debate as to whether harvesting prescriptions can be used to successfully enhance old-growth attributes. In excess of 200 years is required for development of Douglas-fir old-growth and associated large broken-topped trees or spreading crowns (Franklin and Spies 1991) and old-growth development is site-specific and highly impacted by natural disturbances acting through time (Agee 1991). Hershey et al. (1998) note that "there is no evidence as yet that silvicultural prescriptions can be designed to produce all of these features rapidly"; they caution that such methods should be applied only to stands currently unoccupied by spotted owls.

In the Pacific Northwest, small mammal prey populations of the Spotted Owl were compared across a range of forest ages to aid development of forest management guidelines where recovery of Spotted Owl and enhancement of biodiversity are the management objectives (Carey 1995). Flying squirrel populations were twice as high in old forests as in managed forests without old-growth legacies such as large snags and coarse woody debris, but were similar in managed forests with old-growth legacies. Flying squirrel populations were predicted most accurately by prevalence of ericaceous shrubs, abundance of large snags and stand origin. These three factors appeared to be independent of stand age, suggesting that silvicultural manipulation could be used to accelerate development of Spotted Owl habitat and restore old-growth conditions where they are currently lacking. Carey (1995) cautions that his research does not indicate that silviculture can be used to produce all the functions and processes of old-growth forest, however this form of ecosystem management can be used to create habitat and conserve biodiversity.

Example 4: The Washington Forest Landscape Management Project

This case study highlights the potential to manage large areas of second-growth hemlock/Douglas-fir forest for multiple species of threatened, endangered and old-growth dependent wildlife (Carey et al. 1996). It compares the effect of three management scenarios (“no-management” pathway; “biodiversity” pathway; and “maximize timber” pathway) on biodiversity and timber values. Using a SNAP-II simulation model, field data gathered within the landscape were used to run a base case simulation over a 300 year period. Results suggest that a modified version of commercial thinning (“variable-density thinning”) implemented at the competitive exclusion phase of forest development will speed up growth (Tappeiner et al. 1997) and stimulate development of diverse and patchy understories that mimic old forests (Carey et al. 1996). This approach avoids excessive brush production, yet allows variable understorey development while reducing the probability of windthrow, when compared with conventional thinning. The authors caution that if poorly executed, thinning may result in high brush cover and no regeneration (A.B. Carey pers. comm.).

The study concludes that old-seral attributes can be developed through management practices, providing the forest is in the competitive exclusion stage and treatment prescriptions ensure retention of appropriate ‘legacy features” (e.g., large, old live and dead trees) and shade-tolerant regeneration (A.B. Carey pers. comm.). One main conclusion from the model is that, *assuming an initial landscape which is predominantly second-growth managed forest*, management intervention results in forests with old attributes more rapidly than does management exclusion. However, the authors acknowledge that “forests with older seral characteristics” differ from old-growth forests which have “spiritual and metaphysical values unexplainable by science” (A.B. Carey pers. comm., Carey et al. 1996).

Applicability of these results to forests in the B.C. interior depends on the state of the forest prior to management (i.e., first or second-growth) and whether appropriate structural features are currently lacking. Many interior forests are first growth but have been impacted by extensive burning combined with high-grade logging earlier in this century. Apparently ‘natural’ stands may therefore lack important structural features and enhancement of these attributes would effectively increase old-growth recruitment.

Summary

Old-growth management in British Columbia is primarily directed by the FPC *Landscape Unit Planning Guide* (Province of British Columbia 1999a) and the FPC *Biodiversity Guidebook* (Province of British Columbia 1995a). The latter recommends retention of a percentage of each BEC zone (by landscape unit) in old-seral forest conditions as Old-Growth Management Areas (OGMAs). Deficits in old-seral stands are apparent in some areas and old-growth recruitment may be a feasible management strategy.

Old-seral stands often exhibit high variability and structural diversity with typical species composition. Theoretically, thinning mature stands may (i) change mid-seral species composition to later seral shade-tolerant species, (ii) allow competitive release and increased mean annual increment of remaining trees, and (iii) provide patchily distributed gaps and understorey development. The lack of studies addressing old-growth recruitment hinders identification of target forest types for thinning treatments, however some generalizations are possible. Forest types and stands most suitable for old-growth recruitment through partial harvesting are those:

- in the competitive or stem exclusion phase;
- in landscape units or BEC zones where old-growth is currently in deficit;
- in landscape units or BEC zones where prior land use has targeted large structural attributes for removal (e.g., high-grade logging); and
- with some existing old-seral stand structural attributes.

It is generally acknowledged that partial cutting systems can create or enhance wildlife habitat and favor biodiversity. Important issues relating to old-growth recruitment through partial cutting include creation of canopy gaps, the particular forest development patterns that are influenced by harvest entries, retention or recruitment of large-sized trees in various stages of life, death, and decay, and the size and connectivity of old-seral patches.

3.1.2 Riparian Management Areas

Provincial Management Direction

The FPC *Riparian Management Area Guidebook* (Province of British Columbia 1995b) defines riparian habitat as "areas that occur next to the banks of streams, lakes and wetlands, and include both area dominated by continuous high moisture content, and the adjacent upland vegetation that exerts its influence on it". Riparian guidelines attempt to maintain the unique features and functions of riparian ecosystems across landscapes by focusing on Riparian Reserve Zones (RRZ) and/or Riparian Management Zones (RMZ), collectively termed the Riparian Management Area (RMA). Widths and specific management practices in RRZs and RMZs are dependent on the stream classification (S1 – S6). Regional lakeshores and wetlands have similar reserve and management zones (Province of British Columbia 1996).

The objectives of Riparian Management Areas (Province of British Columbia 1995b) are stated as:

- minimize or prevent impacts on stream channel dynamics, aquatic ecosystems and water quality of all streams, lakes and wetlands; and
- minimize or prevent impacts on the diversity, productivity, and sustainability of wildlife habitat and vegetation adjacent to streams, lakes, and wetlands with reserve zones, or where high wildlife values are present.

In particular, forest management practices within the riparian management zone should:

- reduce risk of windthrow to the reserve zone (where present);
- retain important wildlife habitat attributes (wildlife trees, large trees, cover, nesting sites, structural diversity, coarse woody debris, and food sources) characteristic of natural riparian ecosystems;
- retain sufficient vegetation along streams to provide shade, reduce bank microclimate changes, maintain natural channel and bank stability, and (where specified) maintain important attributes for wildlife; and
- retain key wildlife habitat attributes characteristic of natural riparian ecosystems adjacent to lakes and wetlands.

Stand structural targets

Riparian areas can be classified as the land that influences or is influenced by a body of water whose specific characteristics differ with the geomorphology, soils and vegetation type present (Gregory and Ashkenas 1990). Their biological importance has been reviewed in great detail (e.g., Voller 1998). Stand structural definitions do not exist for riparian habitat, so prescriptions must be developed on a site-specific basis. However, the following unique features are associated with riparian systems and should be included in management prescriptions whenever possible:

- vegetation which provides bank stability, regulated stream flow and relatively stable temperatures to maintain natural invertebrate communities (Gregory and Ashkenas 1990);
- presence of large-sized woody debris within and around streams to maintain habitat for fish and other aquatic species (Harmon et al. 1986; Hamilton 1991);
- highly productive soils which result in relatively large tree sizes, often with a high deciduous component and different communities than adjacent upland (Schoonmaker and McKee 1988);
- high probability of live and dead veteran trees present due to low disturbance probability (Agee 1994);
- natural corridors in the landscape which tend to escape natural disturbances, particularly in fire-dominated ecosystems (Agee 1994);
- habitat for riparian wildlife species, particularly amphibians and reptiles (e.g., Aubry and Hall 1991);

- relatively rare site series and thus plant communities within the landscape; and
- capacity for rapid transport of nutrients, energy and impacts between different parts of the riparian ecosystem.

Riparian systems in 'unmanaged' forest do not necessarily possess a full compliment of these features because of widespread high-grading earlier this century. Partial harvesting in RMAs should aim to maintain or restore (in degraded or second-growth forests) these features.

Partial cutting considerations

Industrial forestry has negative impacts on riparian systems (Orchard 1990; Gregory et al. 1991; Naiman et al. 1993; Dupuis 1993) and the potential for partial cutting to mitigate the effects of current forest practices on biodiversity values is explored in this section. The Forest Practices Code formulates fixed-width buffer strips (RMAs) to maintain the ecological functioning of riparian areas (Province of British Columbia 1995b). The efficacy and dimensions of buffer strips to maintain the integrity of riparian ecosystems is still widely debated (Belt et al. 1992; Bren 1995; Darveau et al. 1995). Strips are known to reduce temperature fluctuations in streams of all sizes, which in turn regulates diversity and abundance of stream invertebrates (Newbold et al. 1980; Belt et al. 1992). They may also mitigate the increased sediment input (which has wide-ranging and cumulative impacts on stream micro and macrofauna) associated with logging activity (Carlson et al. 1990). Buffer strips which specifically retain important riparian attributes may also alleviate the impacts of logging on vertebrate populations. Along boreal forest streams, 60 m wide buffer strips were required to maintain the bird community (Darveau et al. 1995); partial cutting in buffers resulted in a lower decrease in species diversity than did reducing buffer widths (Darveau et al. 1995). Appropriate buffer width sizes are largely unknown and depend on the specific objectives for the RMA.

Riparian management policy in B.C. incorporates a combination of 'no harvest' RRZs on large-sized streams and RMZs with some harvest on smaller streams. In RMZs, *best management practices* involving the use of partial cutting to retain important features should be met. However, riparian guidelines are not mandatory and it is unclear how well prescribed practices meet these guidelines and their stated objectives. The potential for using partial harvesting to enhance or maintain biodiversity values in RMAs depends on current management practices in RMAs. The latter are briefly addressed in the following section.

Riparian management practices

In 1998, a post-*FPC Code* review of riparian practices in a sample of 34 non-randomly chosen cutblocks was conducted in the Nelson Forest Region (Baudry et al. 1998). The review does not clearly address practices within each RMZ, however available silviculture prescriptions for these cutblocks were analyzed to assess trends. This analysis was based on the silviculture prescription only and on-site practices may be different; departures from the silviculture prescription were noted both in terms of higher and lower levels of retention than specified (D. Hamilton pers. comm; M. Madill pers. comm). Of 32 streams total, 53% of RMZs were clearcut, 34% were partial cut (of 11 cutblocks total, 4 had understorey retention only and 5 were the same seedtree prescription as the remainder of the block) and 12% were intact. Practices in RMZs were generally the *same as those in the remainder of the block*, according to reviewers that conducted on site assessments. In cases where slope breaks determined the RMZ boundary, 100% retention was likely, however most RMZs were clearcut with no provision for retaining special habitat features (M. Madill, G. Beaudry, and D. Hamilton pers. comm.).

This review suggests that the intent of the riparian guidelines is not being met. Either blocks are located away from riparian areas (effectively resulting in 100% retention) or the RMAs are either clearcut or have minimal retention of riparian values. There is a need to promote site-specific partial cutting in RMAs, rather than clearcutting to enhance post-treatment riparian values.

Within Tree Farm Licence (TFL) 6 on Northern Vancouver Island, it was noted that no incremental fiber production was available in RMZs (although promoted by the riparian guidebook) because close to 100% of the RMZs were clearcut, often resulting in the blowdown of RRZs following high wind speed events (Simons Reid Collins 1998).

Summary

Riparian management practices in British Columbia are formulated in the FPC Riparian *Management Area Guidebook* (Province of British Columbia 1995b). The goal of the riparian guidelines is to maintain the unique features and functions of riparian ecosystems across landscapes. Riparian Management Areas (RMAs) consisting of Riparian Reserve Zones (RRZs) and/or Riparian Management Zones (RMZs) are promoted as an approach to minimize negative impacts on stream channels and riparian biodiversity.

In most areas, RMAs are best left untreated. Where severe forest health problems threaten the integrity of RMAs, partial cutting may be appropriate. Partial cutting may also be feasible in previously degraded areas which lack large structural attributes typical of riparian ecosystems, in low windthrow areas with stable soils and in relatively dry/mesic sites. As an alternative to clearcutting and low retention silviculture systems, single tree selection harvesting for specialty wood products is likely more effective for maintaining biodiversity.

3.1.3 Lakeshore Management Areas

Provincial Managment Direction

The FPC *Lake Classification and Lakeshore Management Guidebook: Nelson Forest Region* (Province of British Columbia 1996) states biodiversity objectives ranging from "maintaining all key lake attributes" to "managing landscape biodiversity by maintaining ecosystem linkages to adjacent landscape features where they exist", depending on the classification of the lake. Lakeshore management areas (LMAs) consist of a riparian reserve zone (adjacent to the lake) and a lakeshore management zone (LMZ).

Harvesting is not permitted within 10 m reserve zones (for lakes between 5 – 1000 ha in size) but can occur within LMZs. The following general recommendations for appropriate silviculture systems include (Province of British Columbia 1996):

NDT1:	single tree or group selection when silviculturally appropriate and technically feasible; otherwise clearcut with reserves and/or extend edge of riparian reserve;
NDT3 and 4	Douglas-fir and ponderosa pine leading: single tree or group selection with wildlife tree reserves;
NDT3 and 4	lodgepole pine or spruce leading: clearcut with reserves and/or extend boundary of riparian reserve zone;
NDT2:	no recommendations are made.

Lakeshore management zones are a special case of riparian management, and will be considered in that context (see Section 3.1.2 above).

3.1.4 Ungulate Winter Range

Provincial Management Direction

Ungulate winter range guidelines differ across regions in B.C. Ungulate species in the Nelson Forest Region include elk, mule deer, white-tail deer, moose and Rocky Mountain bighorn sheep. The intent of ungulate winter range guidelines as defined by the KBLUP (Kootenay Inter-Agency Management Committee 1997) is to "ensure viable populations of all ungulate species". Details for managing winter ranges are given below.

Stand Structural targets

The KBLUP guidelines provide information on key attributes such as (i) appropriate canopy cover capable of intercepting snow, (ii) vegetation suitable for thermal and visual cover, and (iii) canopy gaps or openings which encourage suitable browse production. Detailed guidelines by BEC variant, slope class and ungulate species are available (KBLUP-IS and in regional handbooks). Specific guidelines are not reiterated here (they differ with BEC, ungulate species and region); but some details are found in Appendices 1-5.

The efficacy of using partial cutting to create ungulate winter range is limited by the relationship between snowpack, canopy closure, accessibility and forage availability. In areas with high snowpack, high canopy closure is required to enable movement and forage accessibility, hence partial cutting may be inappropriate in areas with high winter precipitation such as the West Kootenay region (G. Woods pers. comm.; J. Gwilliam pers. comm.).

A general habitat classification for ungulates was developed based on field surveys in the Pend d'Oreille valley of the southern Arrow Forest District (J. Gwilliam pers. comm.). This dry ecosystem classification separates cover into three classes (excellent, mid and marginal) and also defines suitable recruitment cover areas:

Cover:
1. excellent – Douglas-fir leading, age class ≥6; crown closure ≤5 (46-55%)
2. mid range – Douglas-fir leading, age class ≥6; crown closure 3-4 (26-45%)
3. marginal – Douglas-fir leading, age class = 5; crown closure ≤3 (26-35%)

Recruitment cover: Douglas-fir leading, age class <5; crown closure ≤3 (26-35%)

Forage: open forest or non-forest types with crown closure <3.

Seasonal requirements forage, cover and thermal requirements of ungulates necessitates landscape-level planning to maintain (or create) horizontal and vertical structural diversity with patches of high forage quality interspersed with closed canopy forest. Although average snowfalls are an important factor in determining management strategies, consideration of maximum likely snowfall is crucial, since insufficient high quality habitat can result in very high mortality in high snowfall years.

Partial cutting considerations

Example 1: Partial cutting, canopy closure and snow interception

Maintaining sufficient crown closure (to intercept snow and permit movement without high energy losses) in ungulate winter ranges is critical. Basal area has been suggested as a surrogate measure for crown closure (Dealy 1985) and the two parameters are related, but not in linear fashion (Dealy 1985; Johnson 1992). A number of studies that have examined relationships between basal area, crown closure and snow depth conclude that both basal area and crown closure are negatively correlated with snowpack, but the latter measure is a more consistent predictor (Bunnell 1979; Hanley and Rose 1987; Johnson 1992). Focusing on the IDF zone, Dawson and Armleder (1999) recommend that management occur at three spatial scales (regional, landscape and stand) and suggest that different descriptors be used for each level. They recommend using "percentage of Douglas-fir" at each scale, but crown closure at regional and landscape scales only. At the stand level, they recommend that silviculturists use "total basal area" as a descriptor.

Example 2: Structural definitions for management of mule deer winter range in the IDF zone – Cariboo Forest Region.

Maintenance of critical mule-deer winter range in the Cariboo Region (mainly IDF zone) is a goal identified in the Cariboo-Chilcotin Land Use Plan. Although general guidelines for maintaining mule deer winter range have been available for a number of years (Armleder et al. 1986), more specific stand-level requirements have now been developed (Dawson and Armleder 1999).

The approach outlined involves:

1. a regional and landscape-level analysis of the desired crown closure objective for a particular stand;

2. identification of specific minimum residual basal area targets required to meet desired post-harvest crown closure objectives; and

3. determination of appropriate residual stem density and basal area curves from residual basal area.

The authors suggest that once the target basal area distribution is determined, options for moving the stand towards that distribution can be evaluated. For example, the stand shown in Figures 1 and 2 could be harvested in the size classes shown above the line and brought to meet targets within one rotation. Alternatively, targets could be achieved over two cutting cycles by thinning from below in the first rotation (resulting in increased growth of the A layer) and removal of all stems in all size classes above the curve during the second pass. This would achieve stand structure targets and would promote regeneration in canopy gaps (from Dawson and Armleder 1999). Higher volume removal combined with longer rotation lengths could be used to move a particular stand between two crown closure types (e.g., high and moderate) over a longer timeframe.

Figure 1. **Example of residual stem density (from Dawson and Armleder 1999).**

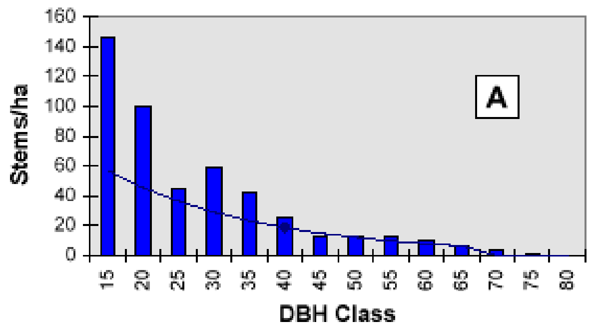
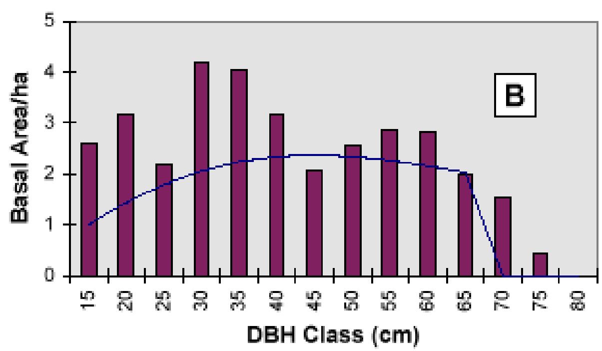


Figure 2. Examples of residual basal area, by diameter class. Bars indicate current structure, and the lines running through bars represent residual stand structure targets (from Dawson and Armleder 1999).



Summary
Ungulate winter range is usually low elevation forest on relatively shallow slopes. Specific biological requirements differ by region and associated species and maximum snowpack levels. In areas with exceptionally high snowfall in some years, large areas with high habitat suitability should not be converted to moderate or marginal habitat, as these areas alone may remain suitable in high snowfall years. Appropriate forest types for partial cutting include:

1. Douglas-fir leading areas with crown closures class > 6 (patchy cutting may enhance browse and maintain required crown closure);

2. Douglas-fir leading areas with crown closure class < 3 (single tree selection of smaller stems may release retained trees, resulting in more rapid canopy closure);

3. Drier ICHdw forests where ecosystem restoration is appropriate (e.g., veteran ponderosa pine with Douglas-fir mature layer and thickets);

4. Areas with high potential suitability, but with unnaturally dense lodgepole pine or Douglas-fir which impede movement and fail to intercept snow.

3.1.5 Caribou Special Management Zones

Provincial Management Direction

Woodland caribou (*Rangifer tarandus caribou*) populations in B.C. are found in a diversity of habitat types, with varying levels of population stability (Stevenson 1990). The mountain caribou ecotype in the southern interior is designated as 'vulnerable' (blue-listed) because of small relatively isolated populations.

The KBLUP *Implementation Strategy* (Kootenay Inter-Agency Management Committee 1997) and associated Memorandum of Understanding (Province of British Columbia 1997) attempts to provide the "amount and distribution of habitat required to maintain viable populations of the several distinct herds of blue-listed mountain caribou". The following operational guidelines apply n caribou habitat:

- In operable ESSF, retain a minimum of 10% age class (AC) 9 and up to 20% AC8 to a total 30% retention. On an additional 20% of the operable landbase, partial cutting is acceptable providing the equivalent clearcut area (ECA) does not exceed 35% total, with green-up defined as ≥ AC7. Figures for the 1998 MOU differ slightly, with retention of 40% of the operable forest in AC 8, with at least 10% in AC9. Of the 40%, 10% is available for trial partial harvesting systems;
- In the operable ICH, retain a minimum of 10% AC9 and up to 30% as AC8 up to a total 40%. Partial cutting is not recommended within the reserve (i.e., the 40%) but is recommended in the remaining 60% of the caribou area (M. Besko, pers. comm.);
- Retain at least 70% basal area above the 1994 operability line;
- Rotation age for all habitats is 151 years;
- Cutblock size in the ESSF ranges from 0.25−100 ha, depending on landscape unit planning process and habitat type;
- Application of all guidelines on slope classes < 80%;
- Restrict access to snowmobiles and avoid road access in upland parkland areas; and
- No harvesting in upland parkland areas.

Stand structural targets

Mountain caribou adjust their habitat use by season and individual herds appear to have specific patterns of habitat use (H. Armleder pers. comm.; Stevenson et al. 1994; Coxson 1997). A number of interrelated factors impact caribou survival, but the three most critical appear to be provision of (i) sufficient security cover, (ii) old-growth stands with high lichen (primarily *Bryoria* species and *Alectoria sarmentosa*) availability for forage (forests < 125 years old provide insufficient lichen loading for caribou) and (iii) a landscape matrix which allows free travel for caribou without channeling them into either unsuitable or highly risky habitat. Conventional clearcut logging with a rotation age of 80-120 years is incompatible with maintaining caribou habitat, since it decreases the proportion of suitable habitat and permanently removes lichen availability, thereby increasing caribou density and predation risk.

In 1988, the Mountain Caribou in Managed Forests Program was initiated to determine whether silvicultural systems and habitat enhancement techniques can be used to sustain both timber harvest and caribou habitat over the long term through (Stevenson et al. 1994). As a result of this initiative and independent research elsewhere, many projects and case studies have been initiated (see summary in Stevenson et al. 1994), but in many cases, results are not yet available (Stevenson pers. comm.).   General stand structural targets and silviculture guidelines for caribou management have been detailed elsewhere (Servheen and Lyon 1989; Stevenson et al. 1994; Hamilton 1997) and are briefly summarized here. Most research focuses on "maintaining" habitat suitability for caribou while allowing timber harvest; although habitat 'enhancement' is mentioned (Stevenson 1990; Stevenson et al. 1994), it is considered a lower priority than alternative silviculture. However the potential for habitat recruitment from younger or managed stands will increase through time (Stevenson 1990).

Within core caribou habitats designated as caribou management areas, general guidelines include:

- volume removal limited to 30% of initial stand volume;
- retention of high lichen loading (which may involve high snag retention);
- retention of 'branchy' trees (with high lichen accessibility);
- maintenance of high canopy closure with multi-layered structure;
- minimal soil disturbance (to prevent enhancement of deer and moose forage); and
- minimal slash (which impedes travel).

In addition, there are stand structure guidelines for caribou habitat management, by season (Table 3).

Partial cutting considerations

Mountain caribou forage primarily on arboreal lichens which are both most abundant on old trees (Stevenson et al. 1994). Light availability and time for lichen to colonize sites limits lichen availability in young seral or pole-sapling stands (Stevenson et al. 1994). Lichen appear to disperse only about 350 m into stands from adjacent mature timber; at greater distances, dispersal is reduced practically to zero (Stevenson 1986). Colonization of individual branches appears to be more successful on surfaces with rough texture (generally associated with older slow-growing branches (Stevenson, in prep.). The implications of this research for managing stands to increase lichen growth have not yet been determined (S. Stevenson pers. comm.). Stand management may increase lichen growth, particularly on moist sites and in stands with low light availability (e.g., young seral stands). In drier sites, moisture content rather than light may be the factor limiting growth, and opening up a stand will decrease stand moisture content and associated lichen availability. Observations of lichen distribution in existing stands may provide clues about the particular limiting factors within a stand, and hence lead to suitable site-specific prescriptions.

Table 3. Stand structural attributes important for caribou in three seasons: early winter, late winter and fall (from Servheen and Lyon 1989).

Season	Description
Early-winter	- low elevation mature to old-growth cedar/ hemlock and spruce/fir stands - 70% canopy closure - high windthrow and high lichen densities - understorey of boxwood - moderate slopes
Late-winter	- high elevation mature spruce/ fir - open canopies (20-50%) - snags - high lichen densities - gentle to moderate slopes
Fall	- low elevation, mature/ old-growth stands - high snag densities - dense understories - moderate slopes

In addition to being present, lichen must also be available to ensure habitat suitability for mountain caribou. At high elevations, lichen availability is largely related to snowpack. At lower elevations (ICH, or transition ICH/ ESSF), lichen is largely available in the form of litterfall (Servheen and Lyon 1986) and negatively impacting litterfall volume will decrease lichen availability. Younger seral or thinned stands both tend to have lower levels of litterfall and individual stem mortality (Stevenson 1986) but thinning to increase light levels and lichen growth may inadvertently reduce lichen availability. Silviculture prescriptions can potentially be used to avoid this problem where it exists.

Partial cutting and lichen growth: Field trials in ESSF stands have examined the impacts of different partial cutting systems on lichen growth rates over a 3-year period (Stevenson in prep.). Overall, *Bryoria* species had higher growth rates than *A. sarmentosa*. *Bryoria* grew at similar rates in clumped partial cuts and in unharvested stands and at faster rates than in a more uniform irregular shelterwood. *A. sarmentosa* grew faster in unharvested stands than in either type of partial cut (Stevenson in prep.). Maintaining lichen populations may therefore be maximized by removing a low volume of wood in clumped patches rather than in more uniform retention.

Extensive literature reviews and associated management guidelines relating to maintenance of caribou habitat while allowing for timber harvest exist (e.g., Servheen and Lyon 1986; Stevenson et al. 1994; Hamilton 1997); many of these recommendations are incorporated into higher level plans (Kootenay Inter-Agency Management Committee 1997). However, there is still debate regarding the most appropriate tactics for maintaining functioning landscapes for caribou populations (H. Armleder pers. comm; D. DeLong pers. comm.).

Example 1: Caribou management in the Southern Selkirks (DeLong et al. 1999)

Several blocks in core caribou habitat within the Engelmann spruce sub-alpine fir (ESSF) zone were partial harvested (single tree and small clumps) in the 1970s and early 1980s. A retrospective analysis of the fate of these blocks was used to assess regeneration, stand development and the suitability of the blocks for caribou (by comparing partially cut stands with currently used stands). Regeneration was high on all blocks (mean of 14,000 sph and all blocks >5000 sph). The majority of regeneration was established post-harvest, however there was significant advance regeneration on some blocks. Regeneration success appeared to be related to the level of soil disturbance associated with the logging practice. Basal area of residual stems in the blocks ranged from 8.7–26.7m^2 (approximately 50% of that in uncut stands), with little evidence of further disturbance (blowdown, root rot, bark beetle or logging damage). Mean crown closures were similar in partial and uncut stands, however sample sizes are small and the variability in these clumpy stands is high. No snags were retained in the partially cut stands (as per Workers' Compensation Board regulations at that time), consequently no lichen was available for caribou on snags. However, overall lichen loading was only slightly higher in the uncut stands (2.4) compared with partially cut stands (2.1). Neither residual basal area nor crown closure were well correlated with lichen abundance. The partial cuts appeared to maintain greater lichen loads of *Bryoria* spp., compared to other caribou foraging areas and in contrast to another experimental partial cutting trial which failed to maintain lichen loads even in the short term (Terry 1994). However, other studies using low volume and group selection methods have also maintained lichen loads (Armleder and Stevenson 1996). It is still unknown whether these blocks provide sufficient lichen availability to support caribou populations through winter, and whether they will be utilized.

Example 2: Caribou management in the Revelstoke Forest District (Waters 1996)

Much of the timber available in the Revelstoke Forest District is constrained by caribou management guidelines, illustrating the need to integrate timber removal with the development of suitable management strategies. In 1994, the Small Business Forest Enterprise Program initiated a field trial to examine whether patch cutting in old-growth interior cedar-hemlock (ICHwk1) stands could simultaneously satisfy timber and caribou objectives (Waters 1996). Stated biodiversity objectives were to: (i) maintain mature and old-growth values on 50% of the stand and (ii) maximize snow interception on 50% of the area in perpetuity. Important issues included ensuring that the remaining stand was windfirm, which called for removing only 30% of the stand volume in the first entry. In addition, maintenance of falsebox (an early winter forage plant), minimizing soil and vegetation disturbance (to avoid encouraging deer and moose forage), avoiding excessive slash (which impedes caribou movement) and retaining 1-4 wildlife tree patches within each patch cut were all included in the prescription (Waters 1996). Total patch size was 71 ha, and 16 patch clearcuts were established, ranging in size from 1.06 – 2.02 ha (total 20 ha). One permanent riparian management area was retained adjacent to the creek (4 ha) and three more passes (removed at year 60, 120 and 180) are planned for the remaining 43 ha.

Harvesting was completed over two winter seasons with a snowpack ranging from 90-250 cm. An EX200 hoe/excavator was used to move wood to designated skid trails (pre-located to minimize site disturbance) and a 518 cat was used for skidding. Wildlife tree patches (consisting of dominant and codominant cedar/hemlock and spruce plus a variety of snags) were retained within each patch cut. These were marked pre-harvest, though in some cases it became necessary to cut some patches to meet Workers' Compensation Board requirements. Directional falling of trees was required (to ensure that residual habitat and worker safety was not compromised) but proved difficult because many old-growth trees had hollow centres, making use of wedges difficult. Locating wildlife tree patches at the edges of cuts could have minimized these operational problems (Waters 1996).

A plantable spot survey was conducted on two patch cuts completed in year 1 of the trial. The number of plantable spots ranged from 1100 – 1200/ ha, which is close to the target stocking objectives (Waters 1996). Monitoring of this block will continue to determine whether the prescription meets the biodiversity objectives of maintaining caribou, whether regeneration seedlings and understorey is satisfactory and how the prescription is impacted by windthrow and snow characteristics in future years. The prescription was operationally feasible on this conventional lower slope site.

Example 3: Caribou habitat recruitment

Areas of 'core caribou habitat' are outlined in different regions across the Province. These areas are determined at a landscape level, and although they consist largely of prime habitat, they may also contain some currently low quality habitat as a result of a fire-history, high-grading or clearcutting. A number of factors limit habitat quality for caribou in these stands:

1. low lichen abundance, due to low light availability preventing lichen growth or low inoculation levels;

2. reduced travel through the stands due to high stem density; and

3. low visibility for predators through the stand.

Lichen biomass can theoretically be increased using a number of approaches:

1. *Juvenile Spacing* - This may increase lichen growth where light is limiting and moisture availability is high (since opening up the stand can decrease water availability and make moisture the limiting factor). Note that thinning may also result in lower abundance of lichen, since litterfall and blowdown are decreased (Stevenson 1990);

2. *Thinning by girdling* - Where lichen abundance is high, girdling creates pockets of snags which increase lichen growth and availability through time (Stevenson et al. 1994);

3. *Lichen inoculation* – Lichen colonization rates depend on the proximity of a source population. Where there are no suitable mature/old stands for colonization (i.e., > 10 tree lengths away; Stevenson 1988), inoculation of stands with lichen may be necessary. Techniques for inoculating stands developed for coastal B.C. (Enns 1988) may be applicable in caribou habitat (Stevenson 1990).

Summary

Caribou guidelines are highly constraining for timber production, however caribou populations are also under threat in British Columbia due to harvesting, disturbance caused by road access, hunting and increases in other ungulate populations. Stand composition (or landscape mosaic) targets are designed to maintain or restore habitats consisting of an interconnected network of old-seral patches. Stand structural targets favor retention of relatively high canopy closure and high lichen densities.

Current guidelines allow some partial harvesting in core caribou habitat, provided suitable features are retained and restoration (or recruitment) of caribou habitat may also be possible. A range of partial harvesting scenarios (from single-tree selection to patch clear cuts of various sizes) have been suggested to maintain caribou habitat. Each approach appears to have its own merits and selection should be determined using a combination of landscape level planning principles and site-specific criteria. Suitable forest types for caribou harvesting include:

1. young seral ESSF stands within core habitats where stem density is high and lichen abundance is low; and

2. ICH winter range outside core caribou habitat, where current suitability is low, but potential suitability is higher.

3.1.6 Wildlife Habitat Areas for Identified Species (Northern Goshawk)

Provincial Management Direction

It is the intention of the FPC to maintain or protect most organisms through the Code's riparian and biodiversity provisions. However, it was determined that these provisions are not adequate to address essential habitat requirements for a subset of species and that (i) general wildlife measures, (ii) wildlife habitat areas and (iii) higher level plan recommendations may be required for the latter. These specific provisions are formulated in the *FPC Identified Wildlife Management Strategy* (IWMS; Province of British Columbia 1999b).

As defined under the FPC, *Identified Wildlife* refers to species or plant communities that are considered to be sensitive to habitat alterations associated with forest and range practices. Volume 1 of the IWMS has recently been adopted as provincial policy (Province of British Columbia 1999b) and identifies 36 species requiring special management attention. Both subspecies of the Northern Goshawk (red-listed *Accipiter gentilis laingi* and regionally important *A.g. atricapillus*) are included. The goshawk was chosen as a focal species for analysis because it is dependent on old-seral forest structure (e.g., high crown closure and abundant large, old trees) and it has large territories; hence it is potentially associated with high timber impacts, relative to other identified species.

Wildlife Habitat Areas (WHAs) are mapped areas that include essential habitats. Forest licensees have a legal obligation to plan and manage these areas. *General wildlife measures* are habitat management practices directed at critical habitats within wildlife habitat areas. These measures are mandatory requirements that must be implemented during forest or range operational planning. *Landscape unit planning considerations* are not mandatory for the interior subspecies of Northern Goshawk. However, the guidebook recommends that consideration be given to designation of high biodiversity emphasis in landscape units where goshawk management is priority.

Implementation of the IWMS may have a maximum of 1% impact on the 1995 allowable annual cut (AAC). Opportunities for timber harvesting within 240 ha goshawk WHAs are limited due to their requirement for forests with high crown closure and high densities of large diameter trees. If the 1% AAC impact maximum is reached through protection of a relatively small number of breeding territories, others will likely not be managed sustainably, resulting in detrimental effects to goshawk populations. Partial cutting entries with silviculture prescriptions tailored to the needs of goshawks may provide greater flexibility for goshawk habitat management.

Stand Structure Targets

Goshawk home ranges are thought to be hierarchically organized and composed of the following types of areas (Province of British Columbia 1999b):

- a *nest site* - a known nest tree and a 1 ha area surrounding it;
- a *nest area* – the active nest tree and one or more alternate nest trees within an area of approximately 12 ha; this area is the center of all breeding movements and behaviors, from courtship through fledging;
- a *post-fledging family area* (PFA) – an area of approximately 240 ha surrounding the nest area; this area roughly corresponds to the defended breeding territory and provides protection to fledglings while learning to hunt; and
- a *foraging area* – an area of approximately 2400 ha (including the PFA) primarily used for foraging activities.

Critical habitats and habitat attributes within each of these habitat units are as follows (Province of British Columbia 1999b, Squires and Reynolds 1997):

- *nest site* – old-seral forest stands with large trees, high crown closure and sparse ground cover with gentle to moderate slopes;
- *nest area* – old-seral forest stands with large trees, high crown closure, moderate slopes with sparse ground cover, usually located close to permanent water;
- *post-fledging family area* (PFA) – 240 ha area consisting, if possible, of 20% old-growth, 40% mature, and the remaining 40% with no more than 20% young forest. The PFA needs to contain (i) patches of dense trees with high canopy closure for goshawk hunting and protection, (ii) developed herbaceous and/or shrubby understories and other attributes important for goshawk prey species (e.g., snags, downed logs and small openings) and (iii) large coarse woody debris, stumps and stubs for goshawk perching; and
- *foraging area* – patches of high crown closure and high densities of large trees with interlocking crowns.

Partial Cutting Considerations

The following considerations are primarily for PFAs (foraging areas may be more heterogeneous). Information sources include the IWMS (Province of British Columbia 1999b), management recommendations for Northern Goshawk in the southwestern U.S. (Reynolds et al. 1992) and the conservation assessment for the Northern Goshawk in southeast Alaska (Iverson et al. 1996). The considerations are:

- layout and establishment of goshawk WHAs should consider opportunities for habitat enhancement through partial cutting;
- only partial cutting systems that maintain high canopy closure (e.g., uneven-aged silviculture with light single tree selection) should be applied;
- retention or enhancement of large, old trees, snags and coarse woody debris;
- timing of operations should be restricted to fall and early winter (October – February);
- old-growth recruitment cuts (e.g., in uniform lodgepole pine stands) that accelerate growth and crown development of retained trees;
- thinning from below, removal of understorey trees with mark-to-cut layout method;
- variable spacing of trees for development of groups of trees with interlocking crowns;
- no stumping or pushover logging (which could impact goshawk prey populations) to reduce root rot incidence; and
- feller bunchers to create stubs within WHAs.

Summary

The Northern Goshawk is designated as an Identified Wildlife species in British Columbia, requiring the establishment of Wildlife Habitat Areas and management according to the General Wildlife Measures. Goshawks require forest stands with high canopy closure and sparse understoriesw, high densities of large-sized trees, and a variety of structural attributes such as snags, coarse woody debris, small openings, stumps and stubs. Light single tree selection cuts that maintain these habitat features are the most appropriate silviculture systems for goshawk post-fledging family areas.

3.1.7 Avalanche Track Management Areas

Provincial Management Direction

The Kootenay-Boundary Land Use Plan (Kootenay Inter-Agency Management Committee 1997) identifies the establishment of Avalanche Track Management Zones (AMZs) as an important measure to provide security cover for grizzly bears which frequently use avalanche tracks for foraging. Similar but more specific management direction is provided in the Nelson Forest Region Memorandum of Understanding (MOU) between the Ministry of Forests and the Ministry of Environment for the preparation of the 1998 Forest Development Plans.

Three priority grizzly bear habitat management areas are recognized in the KBLUP, based on habitat suitability indices. Establishment of AMZs is limited to priority 1 and 2 areas only. Avalanche tracks are ranked as high, moderate or low tracks where "high" refers to herb/forb/grass-dominated tracks, "moderate" refers to shrub-dominated tracks and "low" refers to tracks dominated by regenerating conifers. Furthermore, consideration is given to (i) the number of tracks within a given area, (ii) the dimensional attributes of tracks (e.g., the width of the runout zone) and (iii) adjacency to riparian areas.
A series of interconnected tracks with wide runout zones and herb/forb-dominated vegetation cover within riparian areas would rank "high". Single isolated tracks dominated by regenerating conifers would rank "low". AMZs are to be considered for avalanche tracks that rank "high" or "moderate". Cutblock placement adjacent to high or moderately-ranked tracks is either to be avoided or certain management prescriptions apply (see below).

Stand Structure Targets

According to the Nelson Forest Region MOU, "on slopes with avalanche tracks alternating with strips of forest (>2 tracks/km or < 500 m between tracks), there should be AMZs 50 m in width (or as available) established on one side and around the base of each track where 70% volume retention is maintained. On the other side of the track, a "no harvesting" zone is maintained. On slopes with < 2 tracks/km or > 500 m between tracks, a 100 m AMZ with 70% volume retention applies.

Partial Cutting Considerations

Forest harvesting within AMZs should emphasize retention of cover and maintenance of stand structure and species composition via single tree or group selection partial cutting systems. No more than 20% basal areas removal is recommended on single or widely spaced tracks. Areas between closely spaced tracks should be managed on long rotations with infrequent entries.

Clearcut logging in areas prone to avalanche events (i.e., steep slopes in areas with high snowpack) has resulted in avalanches originating in the clearcuts. Such events have destroyed, for example, parts of adjacent forest stands in the Slocan Valley, Arrow Forest District (Craig Pettitt, Valhalla Wilderness Society, pers. comm). Partial harvest prescriptions likely reduce the probability of creating avalanches due to forestry practices.

3.1.8 Fire-maintained (NDT4) Ecosystems

Provincial Management Direction

The FPC *Biodiversity Guidebook* (Province of British Columbia 1995a) classifies dry, low-elevation ecosystems of the southern interior as Natural Disturbance Type 4 (NDT4), characterized by "frequent, stand-maintaining fires". Biogeoclimatic ecosystem units included in NDT4 are: Ponderosa Pine (PP), Interior Douglas-fir (IDF) and the dry variants of the Interior Cedar-Hemlock (ICH) zone. NDT4 stands experience low-intensity surface fires at 5-20 year intervals. These frequent fires are part of the natural function of dry ecosystems, resulting in a mosaic of grasslands, open forests and clumps of closed-canopy forests, depending on exposure and moisture levels. Typically these stands are characterized by fire-tolerant overstories of old-seral ponderosa pine, Douglas-fir, and western larch and open understories.

Several decades of fire suppression activities in the NDT4 have resulted in tree (mainly Douglas-fir) establishment in previously treeless areas (encroachment) and tree recruitment in open forests (ingrowth). In some areas, tree encroachment and ingrowth are excessive and have resulted in significant changes to the previously dry and open ecosystems (e.g., plant and animal species conversions, stand structural and functional changes and alterations of landscape patterns).

The Kootenay-Boundary Land Use Plan recognizes the need to address the ecological problems in the NDT4 and includes in its Implementation Strategy preliminary management guidelines for fire-maintained ecosystem restoration (Kootenay Inter-Agency Management Committee 1997). Objectives of this management approach include analysis of the appropriate extent and distribution of NDT4 ecosystem components (open range, open forest, and managed forest), stem densities within stands, canopy closure and age-class distribution. An algorithm for appropriate placement of NDT4 ecosystem components has been developed for the Rocky Mountain Trench (Hansen and Bergenske 1998) and the Boundary Forest District (Korol et al. 1999). Through this algorithm, spatial distribution of ecosystem components is defined primarily on the basis of site series, site index and aspect. For forest or range lands which have experienced ingrowth or encroachment, forest management activities such as partial cutting may be used to restore the more natural, fire-maintained conditions of some ecosystems (e.g., conversion from managed forest to open forest or from open forest to open range).

Considering that (i) old-growth targets have been set for landscape units that contain NDT4 ecosystems (FPC *Biodiversity Guidebook*, see also Table 2 in Section 3.1.1 above) and (ii) NDT4 ecosystem restoration is encouraged, integration of these objectives is needed. Note that it is now commonly accepted by forest ecologists and managers that old-seral NDT4 forests are better defined on the basis of stand structure and structural attributes than on the basis of tree age classes derived from Forest Cover Inventory data. Old-seral NDT4 stands, defined in the *Biodiversity Guidebook* as stands >250 years, are, for example, nonexistent in IDF ecosystems of Landscape Units B1, B2, and B3 of Boundary Forest District (Steeger and Hawe 1998). These Landscape Units are designated as High Biodiversity Emphasis Option, therefore requiring a seral stage distribution that includes > 51% of the forested areas as mature plus old-seral (Province of British Columbia 1995a). On the basis of these management recommendations, there is currently a deficit of mature plus old-seral stands of 28%, 45%, and 64% of the target level in Landscape Units B1, B2, and B3, respectively (Steeger and Hawe 1998). Consequently, NDT4 restoration needs to be integrated with old-seral recruitment efforts in these ecosystems.

Stand Structure Targets

For the treed NDT4 ecosystem components (i.e., open range, open forest, and managed forest) the KBLUP Implementation Strategy (Chapter 3, Section 10, Table 2) recommends target stocking levels of 20, 250, and 1000 stems/ha and crown closure maximums of 10%, 40%, and 80%, respectively. Within the open range, the 20 stems/ha are to come from the largest 1/3 of the existing diameter range and within the open forest, 50 of the 250 stems/ha are to come from the largest 1/3 of the existing diameter range. All stems are to be well-spaced.

In an attempt to define desirable stand structural attributes for IDFdm1 ecosystems (site series), Steeger and Hawe (1998) integrated information from a variety of sources (Table 4). These values may be used as preliminary targets until new information requires adjustments. They may also be used to explore opportunities for timber harvesting through partial cutting in these ecosystems, when stocking levels exceed the desired stem densities.

Partial Cutting Consideration*s*

For NDT4 ecosystems in need of restoration or old-seral recruitment, single tree selection with group openings or group selection with reserves are appropriate. Target stems should include excess overstorey and understorey stems. Large-sized and veteran tree and snag retention is crucial and all ponderosa pine, birch, aspen, cottonwood and good quality larch should be reserved. Wildlife tree patches should be established where appropriate and individual wildlife trees should be assessed for hazards to workers and retained if ecologically valuable and safe. Where relevant, consider two entries to avoid reducing stand volume or basal area by more than 30-50% at a time.

Example 1: Old-growth restoration in the Interior Douglas-fir (IDF) zone

An operational trial and case study to restore old-growth forest conditions through partial cutting in the East Kootenay Trench was initiated in 1996 (Hawe and DeLong 1997). This case study addressed the operational, economic and ecological feasibility of old-growth restoration in NDT4 ecosystems. The specific objectives were to modify the stocking levels, species composition and the forest floor to approximate pre-settlement (per-1900) conditions by mimicking the effects of wildfire through a combination of harvesting and prescribed burning on a regular 20-year cycle.

The 30-ha stand is located in the IDFdm2 biogeoclimatic variant of Cranbrook Forest District. Forest cover included patches of (i) large old ponderosa pine with little understorey, (ii) Douglas-fir and ponderosa pine overstorey with dense fir understorey and (iii) smaller stems of Douglas-fir with some western larch. Species composition was approximately 75% Douglas-fir, 20% ponderosa pine and 5% western larch. Large snags with high wildlife use (e.g., cavity nesters) were abundant throughout the stand and *Armillaria* root disease was present throughout.

Table 4. Ideal stand structural attributes for use as targets for maintaining or recruiting old-seral forests in specific site groupings in the IDFdm1 (from Steeger and Hawe 1998).

STAND ATTRIBUTES / SITE SERIES	Dry 02 / 03	Mesic 04 / 01	Moist 05	Wet 06 / 07
Species	Py Fd	Py Lw Fd Pl	Lw Fd Pl Sx Ep At	Fd Pl Sx At Ac
Min. # stems/ha > 50 cm[1]	n.a./ 17	30 / 17	33	17
Min. # stems/ha > 40 cm[1]	n.a. / 70	72 / 86	80	86
Min. # snags/ha > 50 cm[2]	2	2	2	2
Bark	Thick (Py, Lw, Fd)	→		Thin (Pl Sx At)
Old Tree Characteristics (large limbs, sweeps/crooks)[3]	Common	→		Less common
Defect or rot in large trees[3]	→	common throughout		←
Age Structure	Multi-aged overstorey patches	→		Small even-aged patches
Understorey regeneration	Infrequent patches	→		Frequent dense patches
Stand Structure	Mostly single-storied	→		Mostly multi-storied
Gaps/Openings	Frequent	→		Less frequent
Patch Size	Very small (0.35 ha)	→		Variable
Coarse Woody Debris	Very little amount	→		Low to moderate amount
Basal Area/ha[4]	4 / 8-10	12 - 20	16 - 20	20 - 25
Max. Stems/ha (>12.5 cm dbh)	20 / 100 [5]	250 [5]	600 [6]	600 / 400[6]
Max. Crown Closure %[5]	10 / 30	30-50	50-80	50-80

[1] Numbers are recommended mean values with the exception of site series 02 (non-forested to open range) so no minimum standards are given; 03 standard (>40 cm) is reduced to reflect desired basal area.

[2] This appears to be a reasonably risk-averse, across-the-board figure for use until better numbers are available for each site group.

[3] Many large stems should meet these criteria; at least some large stems should be >140 years old.

[4] Based on recommended levels for similar types (Fiedler et. al. 1994), and relative productivity (Braumandl and Curran 1992).

[5] Based on discussions with Tom Braumandl, Regional Forest Ecologist, Nelson Forest Region and Greg Utzig (Kutenai Nature Investigations), and on the KBLUP Implementation Strategy. Numbers apply to mature stands only (i.e., age classes ≥6). More stems will be accepted initially in younger stands (up to target basal area). Note that stems do not have to be well-spaced.

[6] Based on uneven-aged stocking standards (FPC *Establishment to Free Growing Guidebook*, Province of British Columbia 1995c); numbers are for mature stands only (for younger stands and spacing see above).

Prescription development was based on a stump survey (the area had previously been high-graded), research on pre-settlement stand conditions and cruise compilations. Pre-harvest, target residual and actual residual stand conditions are described in Table 5. Ten wildlife tree patches were established within the cutblock, protecting about 35% of all snags (100 stems) in 10% of the block area. The latter had little impact on available timber.

Harvesting was conducted in winter with a Caterpillar D4, a 518 Caterpillar skidder and a John Deere 640 skidder. A total of 1,600 m^3 of sawlogs and 68 m^3 of pulpwood was harvested which was economically feasible at that time, although a larger block size would have improved feasibility. No significant operational impediments were encountered and the trial was considered successful as target conditions were met for most parameters and many old-growth structural attributes were retained. Overall, it was concluded that partial cutting for old-growth restoration in the IDF biogeoclimatic zone is feasible.

Table 5. Stand descriptions (stems ≥17.5 cm dbh) from Hawe and DeLong (1997).

	Pre-harvest stand	Target residual stand	Actual residual stand
Species composition	Fd75Py2Lw.5	Py4Fd4Lw2	Fd6Py3Lw1
Stems (no./ha)	786	75 + some thickets of unmerchantable stems	123 + some thickets of unmerchantable stems
Basal area (m^2/ha)	27	9-15	16
Mean diameter (cm)	20	50	41
Volume (m^3/ha)	185	N/A	128

Example 2: Effects of partial cutting on old-growth structure and function in the IDF

As part of an experimental old-growth research project in the Enhanced Forest Management Pilot Project area of Invermere Forest District, four IDFdm2 stands were partially harvested in 1997 (Steeger and Quesnel 1998, Quesnel et al. 1999) to test whether old-growth stand structure and important wildlife values can be maintained after partial cutting. The research design included six treatments units in the IDFdm2, ranging from approximately 8.5 - 25 ha in size. Two units were untreated controls, two were treated with a 30% basal area removal and the remaining two were treated with 60% basal area removal. “Cavity nesters” were selected as the focal wildlife guild for this project because they and are sensitive to the removal of old-seral stand structural attributes and they comprise the majority of vertebrate wildlife species in these stands. Pre- and post-treatment data on stand structure and density of breeding cavity nesters was collected in 1997 and 1998, respectively.

Pre-treatment data for wildlife was used to help develop site-specific silviculture prescriptions. Current and future wildlife values are being retained or managed through (i) establishment of wildlife tree patches that contain large trees, trees currently used by wildlife and ecologically valuable but unsafe snags and hazard trees and (ii) retention of a variety of large-sized trees (live but diseased or defective trees or seed trees) outside of patches. In addition, a series of marking rules for live tree retention was developed. These marking rules include all deciduous trees, all stems of good form < 17.5 cm dbh, up to 50% live but defective trees in the largest diameter classes and trees in a clumped distribution. For IDFdm2 treatments, preferred tree species for retention were ponderosa pine, Douglas-fir, western larch and lodgepole pine in that order. Trees with diameter >50 cm were also given preference for retention.

Preliminary results after one year post-treatment indicate that the number of breeding cavity nesters did not change significantly on all treatment units (Steeger and Quesnel 1998), suggesting that sufficient breeding structures were retained despite the reduction in basal area. Still, the density of veteran snags (snags >50cm dbh) important to cavity nesters was reduced from 22-33% (from an initial density ranging from 0.4 - 2.8 stems/ha). Removal of small stems (< 17.5 cm dbh) is still required for creating a more open stand structure in these ecosystems. Similar to Hawe and DeLong (1997), the preliminary results of these operational trials suggest that partial cutting is feasible to retain old-growth conditions in NDT4 ecosystems.

Summary
Management direction for the fire-maintained (NDT4) ecosystems of the B.C. southern interior calls for ecosystem restoration activities (e.g., reduction of forest encroachment on open range, reduction of forest ingrowth in open forests and re-introduction of periodic burns). Related biodiversity issues that need to be integrated into dry ecosystem restoration are (i) old-seral recruitment (due to a significant deficit in old-seral stands), (ii) ungulate winter range considerations (due to the high value of these habitats in NDT4) and (iii) requirements of identified wildlife species (due to the large number of vulnerable, threatened, endangered and regionally important species).

The main constraint to forest harvesting in NDT4 ecosystems is the restriction on cutting large stems as these are essential stand structural components driving many of the NDT4 ecosystem processes. Only in stands where large-sized trees are in excess of target values would cutting of large trees be appropriate and there may be few opportunities. On the other hand, a considerable volume of small to medium-sized trees may be available to the forest industry through prescriptions aimed at reducing forest encroachment and forest ingrowth in open range and open forests respectively, old-growth recruitment and habitat enhancement for ungulate forage production.

3.2 Partial Cutting: General Considerations

Many ecological and forest management issues regarding partial cutting are relevant to management of biodiversity. Partial cutting issues relating to windthrow hazard, ectomycorrhizal fungi, forest health agents, Workers' Compensation Board safety regulations and landscape management are addressed in this section.

3.2.1 Partial Cutting and Windthrow Hazard

An often-used objection to partial harvesting is the increased potential for windthrow to residual trees within the block. A number of studies have addressed windthrow directly, and management handbooks exist to provide guidelines for reducing windthrow (Stathers et al. 1994).

In the ICH zone at Date Creek (Prince George Forest Region), experimental treatments of 30 and 60% volume removal in a range of canopy opening sizes were established by removing single trees to create 0.5 ha openings in the partially-cut treatment units and single large openings in the clearcut treatment units. This range of silviculture treatments had little effect on wind damage to merchantable trees (Coates 1997).

A partial cutting trial designed to maintain caribou habitat on two blocks in 200-300 year old ESSFwk1 stands in the Prince George Region was initiated in winter 1989 (Stevenson et al. 1994). Single tree selection was used to remove 52% of the volume in the overstorey, using a diameter limit of 35 cm. A WCB variance was obtained to retain snags with high lichen loading. On one of the two blocks, heavy blowdown of the large-crown trees occurred in the second winter after logging. However, this was *post hoc* acknowledged to be due to an inappropriate silviculture prescription and volume removal for this cutblock, since the area is exposed and known to experience high winds (Stevenson et al. 1994). There is extensive literature on the subject of windthrow and extensive damage due to windthrow can be avoided if silviculture prescriptions are designed with this stated objective.

3.2.2 Partial Cutting and Ectomycorrhizal Fungi

The role of individual ectomycorrhizal fungi in ecosystem processes is largely unknown. However, associations between ectomycorrhizal fungi and conifer root systems are essential for seedling establishment, growth and tree nutrient uptake (Villeneuve et al. 1991; Amaranthus and Perry 1994). The experimental field trials at Date Creek (Coates et al. 1997) were used to examine the impact of partial harvesting regimes and opening size (50-75m diameter) on ectomycorrhizal fungi associated with western hemlock seedlings. Although there was little soil disturbance and seedlings established rapidly, average fungal richness decreased from 13.1 morphotypes under the canopy to 9.6 (28% reduction) at the edge and to 7.8 (40% reduction) in the forest opening (Kranabetter and Wylie 1998).

In the Sicamous Creek Silvicultural Systems Project (Kamloops Forest Region), the impact of five treatments in 30 ha cutblocks (control, single tree selection with 33% volume removal, 0.1 and 1.0 ha patch cuts and one 10 ha clearcut) were examined with respect to a number of response variables. One and two years after treatment, ectomycorrhizal fungi diversity was lower in the center of the 10 ha clearcut compared with points up to 25 m from clearcut edges or in undisturbed forest (Jones and Durall 1996; S. Hagerman pers. comm.). Although no differences in ectomycorrhizal diversity were detected among the three silvicultural systems, the observation that diversity declined with distance from forest edge implies that small, early-seral patches will retain a higher diversity of mycorrhizae because they have a greater perimeter to area ratio.

Hypogeous sporocarps are underground fungal fruiting bodies used as a food source by many small mammals such as squirrels and chipmunks (Machmer and Steeger 1995). The symbiotic relationships between mycorrhizal fungi, trees and small mammals are essential for proper forest ecosystem function and should be considered in the design of partial cutting prescriptions. Establishment of wildlife tree patches within partially cut stands are likely the most feasible management tool for maintaining the functions of mycorrhizal fungi communities.

3.2.3 Partial Cutting and Forest Health Agents

The impact of forest health agents such as tree diseases and insects on forest stand structure and function is, in part, related to tree species composition and density of susceptible trees. Partial cutting has the ability to change both of the latter parameters to improve forest health, if prescriptions are tailored to specific forest health problems. The relationship between partial cutting and two of the most significant forest health agents in the southern interior of British Columbia, namely *Armillaria* root disease and bark beetles e explored in this section.

Armillaria root disease - In the southern Interior, the root disease *A. ostoyae* occurs in the IDF, ICH, MS, ESSF and SBS biogeoclimatic zones. Its principal hosts are living conifers but broad-leaved, deciduous hardwoods and shrubs may also be attacked. *A. ostoyae* is highly pathogenic and can kill vigorously growing trees throughout a rotation (Morrison et al. 1991). However, susceptibility to *Armillaria* varies depending on host species, age and vigor, as well as on environmental factors such as soil conditions and wildfire.

Because the root disease colonizes stumps of broken or cut trees where it may persist for years, partial cutting and precommercial thinning potentially increase its' spread to retained or regenerating trees. Morrison et al. (1991) suggest that repeated partial cutting entries (e.g., every 15-20 years) often result in severely infested sites. The authors suggest that shelterwood and seed tree harvesting systems probably increase the spread of the disease less than do single tree selection systems but more than clearcutting systems (Morrison et al. 1991).

While *A. ostoyae* has negative effects on the production of merchantable trees, it is also an important ecosystem component (for a detailed review of BC *Armillaria* studies see Davies and Machmer 1998). As a mortality agent, the root disease has a strong influence on forest structure and productivity and contributes to the ecological diversification of forests by playing roles in:

- nutrient cycling through tree mortality (Schowalter and Filip 1993, Kile et al. 1991);
- creating wildlife habitat for cavity nesters (Steeger and Hitchcock 1998) and enhancing diversity of vegetation species through the development of canopy openings (e.g., via tree deformation and mortality); and
- selective tailoring of tree density and species composition to site-specific conditions (Goheen and Hansen 1993, Schowalter and Filip 1993, Kile et al. 1991).

Armillaria root disease management guidelines have been formulated in the provincial FPC *Root Disease Management Guidebook* (Province of British Columbia 1995d) and refined for application in the Nelson Forest Region by Norris et al. (1998). With respect to partial cutting, the FPC *Root Disease Management Guidebook* (p. 36) states that "partial cut harvesting or commercial thinning of any root disease infected site should be carefully reviewed before any prescription is submitted or approved". The regional guidebook provides a risk assessment matrix for silviculture prescriptions and corresponding treatment options. "The risk assessment matrix is a conceptual key or problem analysis tool that supports the five-phase procedure for prescription development described in the *Root Disease Management Guidebook*" (Norris et al. 1998).

Both the provincial and the regional guidebooks emphasize the need for using mechanical stump removal and pushover logging for *Armillaria* inoculum reduction and discourage partial cutting systems. However, there is a pronounced scarcity of documented evidence that these treatments are effective at controlling the root disease. On the other hand, there is evidence that stump removal does not work in controlling *Armillaria*, especially if it reduces populations of competitors of *Armillaria* such as the saprophytic *Hyphaloma* fungi (Bill Chapman, pers. comm.). The effects of partial cutting on *Armillaria* incidence are clearly related to site-specific factors as well as the particular partial cutting system chosen. For example, cutting trees whose root systems are not in contact with other trees in the stand or which are adjacent to less susceptible species such as ponderosa pine or western larch should minimize the spread of *Armillaria*.

Overall, there appears to be a need to integrate the use of partial cutting systems with root disease and biodiversity management objectives. One such case study is currently underway in the Invermere EFMPP area (Sacenieks and Pinnell 1998). This study investigates partial cutting methods in an area with sensitive calcareous soils, significant levels of *Armillaria* and important winter range values for elk. The silvicultural systems used in these trials were single tree and group selection with pushover and conventional hand falling harvesting methods. Preliminary results indicate that both selection cuts were operationally and economically feasible, regardless of harvesting method. While damage to overstorey was insignificant, most of the understorey (especially in pushover treatments) was damaged or killed. Harvesting method and silvicultural system affected soil disturbance levels, with pushover single tree treatments resulting in greater disturbance levels than conventional group selection treatments (although all levels were within silviculture prescription limits). The authors stress that correct harvesting techniques are essential to ensure the success of such treatments and that careful tree selection, marking and adequate supervision are required to meet management objectives.

Bark beetles - The insect group 'bark beetles' is one of the most significant forest health agents affecting forest structure and function in southern B.C. Four species are of particular interest to forest managers, primarily because of their periodic damaging effects on commercial conifers (Province of British Columbia 1995e). These species are mountain pine beetle (*Dendroctonus ponderosae*), spruce beetle (*D. rufipennis*), Douglas-fir beetle (*D. pseudotsugae*) and western balsam bark beetle (*Dryocoetes confusus*). At endemic population levels, they contribute significantly to the persistence of forest wildlife species such as insectivorous birds and bats (Steeger et al. 1998).

In the southern interior, the mountain pine beetle is a major tree mortality agent and prevention strategies are implemented at large scales. Partial cutting systems such as single tree or group selection are frequently employed to create a forest structure with tree spacing unfavourable for bark beetles. This selective harvesting technique is known as "beetle proofing" and may be employed to prevent catastrophic outbreaks (Province of British Columbia 1995e), particularly in lodgepole pine stands. While such management tactics are undoubtedly effective in reducing the spread of bark beetles, integration with biodiversity objectives is needed. Woodpeckers, for example, are to a large extent dependent on bark beetles and associated secondary beetles (e.g., *Ips pini*, *Cerambycid* woodborers) for food (Steeger et al. 1998; Steeger and Dulisse 1997) and these birds play important roles in the natural regulation of bark beetle populations (review in Machmer and Steeger 1995). It is therefore acknowledged that habitat enhancement for insectivorous forest birds and mammals (e.g., bats) may maintain bark beetles at endemic population levels (Miller 1998).

Partial cutting is currently being used to reduce the susceptibility of mature lodgepole pine stands to mountain pine beetle attack in TFL #14 (Crestbrook Forest Industries licence area at Parson, Invermere Forest District) (Province of British Columbia 1998). Of the 52,000 ha net operable landbase in the TFL, approximately 63% is pine leading or pure pine of age class 5 or older. Over 600 ha of pine stands have been beetle proofed on TFL #14 and the following results and considerations are noteworthy (Province of British Columbia 1998):

Silvicultural systems for beetle proofing are best described as preparation or intermediate cuts. Regeneration (for current stocking standards) may not be reliable under a 5x5 m spaced canopy (see below) and additional entries to further open up the stands have been suggested. Tree spacing has been set at three distances (4, 5 and 6 m) during trials. Results to date suggest that the 5 m spacing is more effective for beetle management than the 4 m spacing but that the 6 m spacing was more operationally efficient and cost effective. The 4 m spacing is suitable in heavily stocked stands whereas the 6 m spacing should be applied where significant regeneration (layers 2 and 3) is present. Stand selection criteria include (i) beetle-infested pine have priority for removal (ii) target spacing of leave trees is approximately 5 x 5 m, (iii) leave trees should exhibit good form, vigour, and windfirmness and (iv) retention target is approximately 400 stems/ha and 50% of the pre-harvest basal area. Beetle proofing on TFL #14 is considered economical in stands where volume removal is over 100 m^3/ha or where the average volume of stem removal is more than 0.2 m^3.

On the basis of this case study, beetle proofing can increase forest health and is also feasible for timber production. Prescriptions should incorporate the habitat requirements of natural beetle predators and attempt to promote their biological control function (e.g., retention of wildlife tree patches with valuable nest trees and some beetle-infested trees for foraging; Steeger et al. 1998).

3.2.4 Partial Cutting and Workers' Compensation Board Safety Regulations

In contrast to clearcutting, partial cutting potentially exposes forest workers to hazards associated with residual trees, especially when wildlife trees (e.g., snags and defective trees) are targeted for retention. In the past, the Workers' Compensation Board (WCB) required that all snags be felled during forestry operations. The ecological impacts of this regulation prompted the initiation of the BC Wildlife Tree Program which endeavors to protect wildlife tree habitat through tree assessment and retention procedures (Province of British Columbia 1995a). In support of this effort, WCB has recently modified their definition of "dangerous trees" to allow more flexibility to retain safe snags during harvesting as long as they are assessed as safe by a qualified assessor (Workers Compensation Board and B.C. Ministry of Forests 1997). Alternatively, hazardous but valuable wildlife trees can be retained in Wildlife Tree Patches which function as 'no-work zones' (Province of British Columbia 1995a).

Because dead and defective trees play essential roles in forest ecosystems, WCB regulations for partial cutting operations have implications for biodiversity management. Considering partial cutting entries in areas set aside for biodiversity therefore requires development of silviculture prescriptions that retain adequate numbers of wildlife trees throughout and adjacent to cutblocks as well as along roads, trails, and landings. Safety guidelines for partial cutting to be considered during operational planning phases (i.e., forest development plan, initial layout and design, and silviculture prescription) and harvesting have been developed by Workers Compensation Board and BC Ministry of Forests (1997). In addition, the BC Wildlife/Danger Tree Assessors' Course has been revised to include harvesting operations (Wildlife Tree Committee 1998). In general, care must be taken to ensure that partial cutting systems considered for enhancement of biodiversity values do not compromise wildlife tree habitat.

3.2.5 Partial Cutting and Landscape Management

Partial cutting has both stand and landscape level implications. The majority of this document focuses on stand level issues, however landscape level impacts have the potential to be more far-reaching. In this document, we highlight scenarios where partial cutting can be used to enhance or have minimal impact on the targeted biodiversity objectives. This subject is contentious because of the state of biodiversity policy in B.C. Traditional forestry effectively marginalised biodiversity;: protected areas were considered 'wildlife havens' and clearcutting was used on the remainder of landscape, thereby reducing its value for biodiversity. The intent of the FPC *Biodiversity Guidebook* is to improve the situation for biodiversity by emphasizing better management across the entire landscape and increasing habitat value in general. Wildlife tree patches, riparian and old-growth management areas and wildlife habitat areas all aim to increase biodiversity value in otherwise non-protected areas. In this project, we assess whether partial cutting may be useful in these areas set aside for biodiversity. As outlined above, in some scenarios, management is *necessary* to meet the biodiversity objective however in others, it becomes an issue of trade-offs between 100% of a small number of areas or less protection for a higher numbers of areas. Determining actual values for these trade-offs is almost impossible, however we can assume that the higher the general habitat value in the landscape, the less crucial is any individual forest stand. Hence, if partial cutting was more prevalent in the landscape (compared to clearcutting), then the exact management scenario in each constrained area would be less crucial to the maintenance of biodiversity. This same approach is taken in the FPC *Landscape Unit Planning Guide* (Province of British Columbia 1999a); for example, where a budget for maintaining landscape connectivity is not available, the guide suggests using partial cutting to increase connectivity.

There are potentially negative impacts to biodiversity resulting from partial cutting including (i) a higher percentage of the landscape being disturbed at any one time (assuming a fixed AAC), (ii) a larger road network leading to increased hunting pressure, incidental mortality and disturbance and (iii) increased access potentially decreasing snag and wildlife tree density throughout the landscape (due to WCB requirements, see Section 3.2.5. In general, partial cutting in areas set aside for biodiversity is inappropriate where surrounding landscapes have low or no value for the target biodiversity objective (e.g., in highly fragmented caribou habitats).

3.3 Literature Review Summary

Aside from its application in the management of ungulate winter range, partial cutting has rarely been considered for enhancement of habitat or biodiversity components. In general, there appears to be moderate consensus that partial cutting is useful for restoration, maintenance or enhancement of biodiversity components, given well-developed silviculture prescriptions and careful application on the ground. The most ecologically and socially-acceptable opportunities for this management approach appear to be fire-maintained (NDT4) ecosystem restoration (i.e., partial cutting of ingrown stands) and old-growth recruitment (i.e., partial cutting of young and mature trees such that retained trees increase their growth rates). Opportunities for partial cutting in ungulate winter ranges are decreasing in low elevation forests of the southern interior. Riparian management areas require special attention since current practices often do not adequately protect riparian biodiversity values; site-specific partial cutting prescriptions capable of maintaining riparian values are needed as alternatives to clearcutting in RMAs.

Provincial management direction for the maintenance of both biodiversity and timber values is currently highly variable and tentative. Many initiatives are more appropriately considered as working hypotheses for an adaptive management approach rather than guidelines derived from empirical, scientific inquiries. Although B.C. has a good theoretical framework for the management and conservation of biodiversity components (i.e., a Protected Area Strategy coupled with the FPC biodiversity, riparian and identified wildlife strategies), operational planning and consistent application of guidelines are exceedingly difficult. Partial cutting opportunities in biodiversity set-aside areas are therefore best evaluated on a site-specific basis or in distinct management units for which adequate ecological background information is available.

Stand composition and structural targets are available for some components of biodiversity (e.g., forest cover and patch distribution values for ungulate winter ranges, ecosystem distribution in NDT4 landscapes, stand attribute targets for old-seral stands and WHAs). However, target values are not consistently derived from empirical baseline information and many should therefore be considered hypotheses which require testing. Relevant background information for formulating ecologically sound target values exists at the regional and district levels, but the latter are not readily available. Evaluations of partial cutting opportunities in areas set aside for biodiversity are best conducted on a regional or sub-regional scale where site-specific stand composition and structural targets can be derived.

Partial cutting applications are relatively common in the Nelson Forest Region and have been evaluated in numerous studies. Partial cutting research usually focuses on timber production and related issues such as regeneration potential, growth and yield, soil disturbance and forest health. Hence, the suitability of partial cutting as a tool for meeting biodiversity objectives can only be inferred from existing studies and conclusions vary depending on ecosystem and management objectives. When applying partial cutting systems, special considerations are required with respect to (i) windthrow hazard to the residual stand, (ii) long-term integrity of the forest floor, (iii) sensitive endemic wildlife species, (iv) forest health agents such as *Armillaria* root disease and bark beetles, (v) suitability of partial cutting prescriptions in relation to the surrounding landscape and (vi) Workers' Compensation Board safety regulations.

4.0 AREAS AND FOREST TYPES POTENTIALLY SUITABLE FOR MEETING BIODIVERSITY OBJECTIVES THROUGH PARTIAL CUTTING

Surveys of the literature and personal communications with practicing foresters and ecologists both suggest that stating generalities in regard to appropriate set-aside areas and forest types for partial cutting is difficult, due to the complex interactions between the desired management objectives, stand types and site conditions. Factors which influence stand level management prescriptions include, but are not limited to:

- social values influencing landscape management (e.g., visual, water, timber, wildlife);
- natural ecosystem function;
- landscape condition;
- landscape level objectives (derived from social values and landscape condition);
- existing stand structure;
- site conditions including slope, soils, aspect;
- desired future condition of the stand (stand structural objectives);
- harvesting methods;
- economic feasibility (sensitive to short term market conditions);
- safety; and
- other market influences (certification, boycotts).

Nonetheless, the authors and other experienced practitioners (e.g., T. Quirk, F. Marshall, C. Thompson, H. Quesnel, K. Zielke, D. Hancock, A. Vyse, B. Bedard, D. DeLong; pers. comm.) suggest that it is technically possible to meet a range of landscape level objectives using properly applied partial cutting methods in most forest types of the southern interior. Some generalities are possible by separating out each factor. For example, some biodiversity objectives are more easily met using partial cutting (Section 4.1.1), whereas silviculturally, certain stand types are most suitable for certain types of partial cutting systems (Section 4.2), while economic considerations favour yet other types of partial cutting systems (Section 4.3).

4.1 Biodiversity Rationale

4.1.1 Areas where partial cutting *is necessary* to meet biodiversity objectives

Based on the literature review presented in Section 3 and the focal analyses summarized in Appendices 1-5, partial cutting treatments will be necessary to maintain or restore specific biodiversity components in some forested areas of the southern interior.

Candidate areas for which partial cutting is necessary to meet biodiversity objectives include:

- NDT4 ecosystems
    - NDT4 managed forest ecosystem: partial cut for old-growth recruitment
    - NDT4 open range and open forest ecosystem: partial cut for ecosystem restoration and ungulate habitat enhancement
- Old-growth recruitment areas in landscape units with current old-growth deficits
    - NDT1-3 old-growth recruitment to accelerate meeting seral stage targets: partial cut mature or younger stands retaining existing and potential future old-seral attributes;
    - NDT1-3 old-growth recruitment to enlarge old-growth interior habitat: partial cut adjacent to existing old-growth patches to increase their total size through time.
      No harvesting should occur in old-growth management areas in NDT1-3, except possibly in dry NDT 3 ecosystems (e.g.; ICHdw) which should be re-classified as fire-maintained (Quesnel and Pinnell 1998).
- Areas set aside for biodiversity that are experiencing significant forest health problems *that compromise biodiversity objectives*: partial cut to reduce risk of epidemic pest outbreaks; and
- Ungulate winter range deficient in the appropriate mosaic of open forests with good forage conditions and closed canopy forest with high snow interception and thermal cover: partial cut to create forest gaps for forage (shrub, herb) production and/or to prepare the stand for prescribed burning.

4.1.2. Areas where partial cutting *may be considered* in biodiversity management

In many areas that have been set aside for biodiversity objectives, partial cutting (as an alternative to clearcut silvicultural systems) would increase the probability of meeting objectives. Considering the provincial directive to manage biodiversity within a fixed maximum amount of AAC impact, specific high-retention partial cutting prescriptions (see examples in Appendices 1-5) may be more beneficial to biodiversity than no cutting in a few areas and clearcutting in many other areas. (This "trade-off" is expected to benefit biodiversity on a large scale, while potentially impacting certain biodiversity components on a smaller scale).

Candidate areas for *trade-off* partial cutting include:

- Riparian Management Areas (RMAs): partial cut to improve forest health (e.g., beetle proofing, white pine blister rust treatments) or partial cut rather than clearcut in order to protect reserve zones from windthrow hazard and to retain valuable riparian habitats.

  No harvesting should occur in RRZs.

- Lakeshore Management Zones (analogous to RMAs).

- Avalanche Track Management Zones (AMZs): carefully planned and executed single tree selection removing no more than 30% of the volume in AMZs should maintain grizzly bear and moose habitat, while maintainig sufficient canopy to limit avalanche risk.

- Caribou Special Management Zones: use habitat enhancement cuts to promote lichen growth or to increase accessibility of the stand to caribou, thereby increasing connectivity between suitable habitats.

  No harvesting should occur in reserved core caribou habitats; and

- Wildlife Habitat Areas for Identified Species: for example, Northern Goshawk habitat enhancement cuts to create favourable stand structure for goshawks and their prey.

  No harvesting should occur in WHAs with marginal habitat value.

4.2 Silvicultural Rationale

Based on the literature review and discussion with foresters and ecologists, we conclude that stand types with Douglas-fir, western larch, and ponderosa pine as the leading species are considered silviculturally low risk for partial cutting. Lodgepole pine-leading stands may also be low risk (see Listar 1998), however the risk of windthrow may be high for this species, in some circumstances. Where windthrow hazard is low, there may be partial cutting opportunities for lodgepole pine-leading forest types, especially if other tree species within pine stands are targeted for retention. Table 6 presents some of the silviculture information presented in Listar (1998), augmented with additional information.

Several key considerations in choosing forest types which are favourable for partial cutting are:

- original stand density, origin, and age;
- windthrow risk – Douglas-fir, western larch and ponderosa pine develop tap roots which reduce the risk of windthrow;
- moisture stress - under drier site conditions, Douglas-fir and ponderosa pine seedlings require partial shading to reduce drought-induced mortality; and
- climatic conditions (snow press and mid-summer frost) with limit regeneration success at high elevations in spruce and subalpine fir stands.

Stand conditions most suitable for partial cutting include:

- NDT4 “open forest” ecosystems with significant forest ingrowth;
- NDT4 “open range” ecosystems with significant forest encroachment;
- stands with forest health problems (e.g., lodgepole pine stands susceptible to mountain pine beetle, mistletoe incidence, or mixed species stands with density-induced forest health problems);
- stands with light to moderate *Armillaria* incidence (active *Armillaria* centers can be isolated in Wildlife Tree Patches or designated as areas for species conversion, or other strategies);
- NDT1-3 stands with existing closed canopy that can be maintained with partial cutting;
- stands with little or no historical high-grade logging; and
- higher elevation stands which exhibit clumped stand structures

4.3 Economic Rationale

Opportunities for partial cutting in constrained forests are most feasible if they are economically viable. In this context, “economically viable” means that timber removed via partial cutting is sold and that those revenues at least cover the total costs incurred. It assumes no subsidies for any prescribed treatments.

A significant benefit of partial cutting (not related to biodiversity management) that is difficult to quantify is the socially acceptable access to timber provided by partial cutting versus other “higher impact” systems. Many areas described in this report would not be possible to harvest using conventional forestry techniques. Harvesting some timber in constrained areas may justify additional costs when the alternative may either be no harvesting at all or negative impacts on biodiversity. Operations must consider a “cost averaging” approach to ensure acceptable delivered wood costs over time.

Table 6. Rationale for suitability of different partial cutting systems by stand types (based primarily on Listar 1998).

Leading Species	Shelterwood (incl. uniform, variable density, natural and group)	Selection (incl. single tree and group selection)	Commercial Thinning	General comments relating to the species
Douglas-fir (Fd)	• acceptable where Fd is climax species (Schmidt 1990); • Weetman and Vyse (1990) do not recommend this system for natural regeneration in wet-belt Fd stands. However, shelterwood systems have worked well in the ICHdw and ICHmw2 on mesic and drier sites. These prescriptions often result in a mix of species typical for dry ICH stands (J. Smith, pers. obs.).	• single tree selection is common in dry-belt IDF (Vyse et al. 1991); • where Fd is climax tree species, group selection is appropriate (Schmidt 1990); • group selection in the dry-belt (A.Vyse, pers. comm); • group selection is generally suitable in the ICH (Smith and Smith 1994).	• recommended in dry-belt sites to increase or sustain growth and may provide some degree of protection from spruce budworm attacks (Vyse et al. 1991).	• mid shade tolerance and windfirmness makes Fd suitable for many partial cutting systems; shade tolerance decreases from drier sites to wetter sites.
Western larch (Lw)	• feasible (Weetman and Vyse 1990, Helms and Lotan 1988); • not often appropriate for species conversion because of inability to predict good seed crops; • two-cut shelterwood system recommended over 3-cut system; • on exposed sites, offers greatest protection for new seedlings (Schmidt and Shearer 1990); • can provide thermal cover in areas with risk of frost damage (Helms and Lotan 1988); • can lead to deterioration of vigour in over-mature stands (Schmidt and Shearer 1990).	• group selection is appropriate (Helms and Lotan 1988); • to reduce dwarf mistletoe infestations, square or rounded openings are preferable to narrow strips or openings with undulating boundaries (Schmidt and Shearer 1990); infected perimeter trees and advanced regeneration should be removed (Schmidt and Shearer 1990).	• stands up to 50 years old have shown diameter increase response to thinning (Schmidt and Shearer 1990); • previously unmanaged Lw stands should be thinned from below rather that from above to decrease residual tree mortality and breakage to snow and ice (Filip et al. 1995).	• site preparation is required (Thompson 1995, Graham et al. 1995); • excellent windfirmness qualities • very shade intolerant; requires sufficient light for establishment and growth (Helms and Lotan 1988); • NE and W slopes most favourable for seedling survival (Schmidt et al. 1976); • common practice today includes the use of spot planting to ensure stocking requirements are met and desired species composition is achieved.

Table 6 continued.

Leading Species	Shelterwood (incl. uniform, variable density, natural and group)	Selection (incl. single tree and group selection)	Commercial Thinning	General comments relating to the species
Lodgepole pine (Pl)	• can be used where windthrow hazard is low and additional shade is required for regeneration (Schmidt and Alexander 1985); • light removal to encourage release of advanced natural regeneration (natural shelterwood).	• only small group selection is appropriate (Schmidt and Alexander 1985); • patch cutting can create a mosaic of age and size classes that reduces the area susceptible to mountain pine beetle at one time (Amman and Safranyik 1985); • in mixed Fd/Pl pine stands, selection systems can promote mule deer winter range attributes (e.g., Fd cover).	• limited application in 60-80 year old unmanaged dense stands to remove special forest products (e.g., posts, rails, grape stakes) (Nelson & Kamloops Regions). • maintain uniform stand structure to avoid windthrow and snow damage.	• partial cutting must consider windthrow hazard. • common practice to "beetle-proof" through light partial cutting entries. • potential for natural shelterwoods in certain stands. • can promote Pl/Sx mix if advanced regeneration is Sx and protected during harvesting.
Ponderosa pine (Py)	• feasible (Weetman and Vyse 1990); • have been used in U.S. in stands similar to IDFdm2 to obtain Py or Lw regeneration within 5 years (Townsley, pers. comm.)	• single tree selection not feasible (Weetman and Vyse 1990); • group selection feasible in the dry-belt (A. Vyse, pers. comm.).	• a preferred residual species when thinning mixed species stands.	• planting is frequently done to augment episodic natural regeneration and to ensure short regeneration delays.
Western hemlock (Hw)	• not recommended primarily due to windthrow concerns.	• windthrow can be a problem and removal of more than one third of the basal area not recommended (Ruth and Harris 1979); • group selection suitable in old-growth cedar-hemlock stands in the ICH (Smith and Smith 1994).	• generally removed from a stand during mixed species thinning operations.	• preferred species to regenerate in multi-aged NDT1 ecosystems (e.g., in cedar-hemlock OGMAs), using group selection systems. • prolific seed producer.

Table 6 continued.

Leading Species	Shelterwood (incl. uniform, variable density, natural and group)	Selection (incl. single tree and group selection)	Commercial Thinning	General comments relating to the species
Spruce (Se) ESSF	• not feasible in old-growth but recommended in second-growth stands (Weetman and Vyse 1990); • seedbed most suitable for 5 years (Coates et al. 1994); • regeneration often starts on logs and root wads (DeLong et al. 1999).	• feasible in old-growth and second- growth stands (Weetman and Vyse 1990); • group selection is suitable for all types of stand conditions (Alexander 1987); • width of cut strip ranges between 15-137m; maximum opening size is 1 to 6 tree lengths (Alexander 1987); • natural regeneration is high using a variety of group selection techniques (DeLong et al. 1999).	• salvage dead and unhealthy trees and trees within 10 m radius of unhealthy trees; commercial thinning is not recommended in highly unhealthy stands (Coates et al. 1994)	• mechanical site preparation is recommended to produce adequate natural regeneration (Coates et al. 1994); • successful partial cutting has been demonstrated where windthrow hazards are accurately accessed and prescriptions match those assessments.
Spruce (Sx) MS	• feasible in second-growth stands but not feasible in old-growth (Weetman and Vyse 1990).	• not feasible in old-growth and feasible in second-growth stands (Weetman and Vyse 1990).	• preferred residual species when thinning Pl dominated stands	• -

The approach taken here is to look at the major variables affecting costs of partial cutting systems and common harvesting methods and compare them to three log market scenarios. Combined with Table 6, conclusions can be reached regarding the economic viability of partial cutting the identified forest types. It is recognized that many factors determine whether a specific cutblock is economically viable at any time. Presented here are combinations of factors that are common to interior conditions, with the following assumptions used in the analysis:

- *Relative Values of Log Sizes:*
  - Sawlogs - 10-20 cm top diameter; log values: $15-20/m^3 (less than peelers);
  - Peeler - 20-30 cm top diameter; average log prices[1];
  - High value logs - >30 cm top diameter; log values: $20-70/m^3 (higher than peelers).

- *Silvicultural Systems:*
  - Shelterwood - harvest sawlogs ; some peelers and high value logs, removing 70% of the volume in the first entry (regeneration cut);
  - Group selection - harvest all trees in openings < 2 tree height in diameter, removing 30% of the stand;
  - Single tree selection - harvest a range of diameter classes, concentrating on smaller diameters and removing 25% of the volume in each entry;
  - Commercial thinning - harvest sawlogs, removing 30% of the stand volume.

- *Harvesting Methods:*
  - Ground based - small skidder or crawler tractor;stump to truck cost[1]: $15-20/m^3;
  - Cable - small highly portable yarder (15 m tower); stump to truck cost[2]: $25-35/m^3;
  - Horse - horse logging (15 m^3/horse/day); stump to truck cost: $30-45/m^3.

Table 7. Economic viability estimates for different partial cutting systems, given three levels of average log prices for the mix of species and log sizes produced from a cutblock.

Silviculture System	Market price			Comment
	$60	$80	$85+	
Shelterwood				
- Ground based	Y[1]	Y	Y	viable in most markets
- Cable	N	Y	Y	need average market values
Group Selection				
- Ground based	Y	Y	Y	viable in most markets
- Cable	N	Y	Y	need average market values
Single tree selection				
- Ground based	Y/?	Y	Y	average market or short haul
- Cable	N	N/?	Y	average market and short haul
- Horse	N	N/?	Y	average market and short haul
Commercial thinning				
- Ground based	N	Y	Y	need average market values
- Cable	N	N/?	Y	average market and short haul
- Horse	N	N	Y	good markets only

[1] Economically viable: Y = yes, N = No, or ? = depending on hauling distance.

Other costs assumptions reflect a typical cutblock scenario for the interior: layout = \$5/m^3; hauling = \$8-15/m^3; stumpage = \$20-25/m^3. These harvesting methods assume average operator production rates. Log hauling rates will vary depending on cycle times. Estimates regarding the economically viability of operations are given in Table 7; final viability decisions will be based on specific field conditions.

5.0 PARTIAL CUTTING SYSTEMS SUITABLE FOR BIODIVERSITY MANAGEMENT

The appropriate partial cutting system for any biodiversity management prescription will depend on the specific objectives required for each constrained area; however, some generalizations are put forward in Table 8.

6.0 LANDSCAPE CONSIDERATIONS FOR PARTIAL CUTTING IN AREAS SET ASIDE FOR BIODIVERSITY MANAGEMENT

NDT4 ecosystems - Partial cutting regimes in dry, fire-maintained ecosystems of Boundary Forest District and the Rocky Mountain Trench will have to be integrated with (i) the newly developed ecosystem distribution guidelines for open range and open and managed forests (i.e., Cranbrook and Boundary NDT4 algorithms), (ii) burning schedules and objectives for re-introduction of frequent fires and (iii) ungulate winter range guidelines. Partial cutting prescriptions should further consider the abundance and distribution of wildlife trees, especially veteran snags, and wildlife tree patches within the surrounding landscape. In general, there is an obvious scarcity of large-sized veteran snags throughout NDT4 ecosystems; hence stand structural legacies should be retained throughout the landscape wherever possible. Landscape considerations for NDT4 operational case studies are given in Appendix 5.

Habitat connectivity - Partial cutting prescriptions need to reflect the habitat objectives for the corridors and patches in question. As discussed in Appendix 2, core caribou habitats may be connected by increasing the habitat suitability of the patches separating them through partial cutting. Similar reasoning applies to habitat connectivity or increasing interior habitat conditions in riparian areas (Appendix 4), between avalanche tracks or old-seral patches.

Landscape Management - The FPC Biodiversity Guidebook (Province of British Columbia 1995a) sets target amounts and distribution patterns for seral stages by BEC zones. The guidebook further states that "a stand can meet the mature seral criteria if, after partial cutting, the residual stand volume and stand attributes are greater than 70% of the natural stand (all original diameter classes are represented in proportion to the average stand profile for the subzone and variant)". Partial cutting prescriptions will have to be evaluated within the context of landscape unit management (see also FPC Landscape Unit Planning Guide, Province of British Columbia 1999a), especially with respect to stand structure criteria, patch size distribution, and green-up and adjacency regulations.

Access Management - If partial cutting is considered in unroaded areas, increased access along roads, spurs, trails and landings may lead to increased firewood cutting and recreational activities; impacts on wildlife habitat and biodiversity are likely. In areas set aside for biodiversity where partial cutting is prescribed, firewood cutting and free use permits should therefore be excluded, and road closures or deactivations may be necessary to protect sensitive species.

Range Management - Cattle grazing is a serious threat to the biodiversity of grasslands (Pitt and Hooper 1994) and forest ecosystems, hence no new grazing permits should be issued following partial cutting of areas set aside for biodiversity objectives. Non- or restricted range use agreements should be renegotiated with known or permitted range users.

Table 8. Potential advantages and disadvantages for wildlife and biodiversity management using different partial cutting systems.

Single-tree selection		Group selection (< 1 ha)		Shelterwood	
Potential Advantages	Potential Disadvantages	Potential Advantages	Potential Disadvantages	Potential Advantages	Potential Disadvantages
- high flexibility in selecting retention or harvest trees; - entire stand retains relatively high seral stage equivalency and potentially biodiversity value; - dispersed regeneration less likely to negatively impact caribou habitat; - produces multi-layered structure (rather than clumps), where relevant; - lowest impact on crown closure; - maintains high forest cover; - maintains favorable microclimate for trees and other plants in extremes such as dry climates and high elevation sites; and - maintains options for future management.	- disturbance due to roads and skid trails throughout stand[1]; - soil impacts throughout stand[1]; - potential for residual damage is relatively high; - loss of snags in majority of stand[1]; - relatively large area impacted for a given wood volume; and - relatively high costs in layout and harvesting.	- low damage to retained stems; - high snag retention possible; - relatively low costs; - relatively low soil disturbance; - relatively low windthrow risk; - high snow retention throughout retained forest (where relevant); - can be used to mimic gap dynamics; - minimizes uncertainty (risk); - relatively easy to harvest; - relatively easy to administer; - maintains options for future management.	- large opening sizes may cause habitat fragmentation.	- maintain age and structural diversity[2]; - provides for future snags[2]; - ensures continued source of coarse woody debris[2]; - with higher retention levels, maintains environment suitable for many forest dwelling wildlife species[2]; - provides microclimatic conditions favorable to the regeneration and early growth of trees on certain sites; - relatively low cost; - low risk of residual damage; - relatively easy to harvest; - relatively easy to administer.	- high windthrow potential on certain sites; - removes most snags; - low thermal and hiding cover value for ungulates.

[1] Unless adequate wildlife tree patches are established;
[2] If a portion of the shelterwood and stand structural attributes are maintained throughout the rotation.

7.0 CONCLUSIONS

Partial cutting appears to be an appropriate management tool for meeting specific biodiversity objectives. In particular, the following areas are likely to benefit from partial cutting:

- dry, fire-maintained ecosystems requiring restoration;
- mature stands appropriate for old-growth recruitment;
- mature and young stands devoid of veteran trees and other stand structural legacies; and
- stands threatened by disease or insect outbreaks.

Areas where partial cutting would have less impact on biodiversity than clearcutting include:

- riparian, lakeshore, and avalanche track management areas;
- caribou special management zones; and
- Northern Goshawk wildlife habitat areas.

No harvesting should occur in riparian, lakeshore and old-growth reserves.

All potential prescriptions should be adjusted to site-specific ecosystem conditions and few generalizations are possible due the high variability in ecological parameters. The concept of using partial cutting prescriptions to meet biodiversity objectives has not been operationally tested and should therefore be developed cautiously, using an adaptive management approach. Well-supervised logging operations with experienced personnel and post-treatment monitoring are key requirements for success.

Stands with Douglas-fir, western larch and ponderosa pine as leading species are most suitable for partial cutting because of windfirmness, regeneration potential, stand composition and structural characteristics. Lodgepole pine-leading stands appear to be intermediate in their suitability for partial cutting and hemlock-leading stands are least suitable. There is consensus however that given the right stand conditions and market conditions, partial cutting appears to be feasible in most forest types.

Selection of particular partial cutting depends on site-specific factors. In general, if minimal impact on the standing structures throughout a stand is desirable (e.g., in riparian management zones, wildlife habitat areas, or old-growth recruitment stands), single tree selection is most suitable. If forest gaps and other small openings are included as stand structural targets (e.g., in ungulate winter range or caribou habitat), group selection cuts are more suitable than single tree selection. Group selection cuts may also be preferable in stands at climatic extremes (e.g., dry open IDF subject to moisture stress or high elevation ESSF with high snow press) because they mimic the forest gaps, small openings and clumped tree distributions characteristic of these stands.

Economic opportunities from partial cutting obviously depend on multiple factors, some of which (e.g., market prices for timber) vary in time; however, some generalizations are possible. Partial cutting in areas set aside for biodiversity will generate primarily small sawlogs that are lowest in value compared with regular sawlogs and peeler logs. The most economical harvesting methods are ground-based, cable and horse logging, in that order. However, all methods may be feasible under favorable conditions.

Systematic application of partial cutting systems will necessitate linkage to higher level planning, landscape unit objectives, landscape uses other than forestry and ecological parameters such as connectivity, patch size, interior habitat and abundance and distribution of stand structural features throughout the landscape.

8.0 RECOMMENDATIONS

8.1 Implementation – specific to biodiversity management

1. Conduct "adaptive management" case studies; some examples are described in Appendices 1-5.

2. Develop an adaptive management old-growth recruitment methodology, using PROGNOSIS as a simulator and predictor of future desired stand structure. Test and refine methodology through operational field trials. The general procedure to establish such trials may involve the following steps (D. DeLong, pers. comm.)

   (i) use pairs of stands (i.e., 1 existing and 1 recruitment old-growth patch) with similar biophysical parameters located within the same BEC variant,

   (ii) determine stand structure profile of existing old-growth patch;

   (iii) develop stand structure profile of recruitment old-growth patch;

   (iv) develop partial cutting prescription for treatment of recruitment old-growth patch to accelerate attainment of the stand structure profile observed in the existing old-growth patch.

3. Consider creation of an "NDT4 restoration fund" to pay for biodiversity enhancement treatments, including harvesting. The benefits accrued from the restored ecosystems include healthier forests and range, more suitable wildlife habitats and reduced threat of catastrophic wildfires. These benefits likely outweigh the costs of paying for some treatments.

4. Consider a test area (or set of complementary test areas) for comprehensive, coordinated and integrated biodiversity management (e.g., areas managed under the provincial Enhanced Forest Management Pilot Projects (EFMPPs) and Innovative Forest Practices Agreements (IFPAs)).

5. In old-seral stands or areas designated as high biodiversity emphasis, conduct thorough pre-harvest surveys for biodiversity components and protect valuable stand structural and functional components.

6. Avoid issuing range and firewood permits in forested areas where biodiversity management is priority and biodiversity values may be threatened by those activities.

7. Require the use of higher retention partial cutting systems in Riparian Management Zones instead of currently common "high grade" practices which leave only small diameter trees and shrubs.

8.2 Implementation – specific to commercial forestry

8. Industry is encouraged to increase processing capabilities of small diameter wood and special and value-added wood products. Small diameter wood will become available through NDT 4 ecosystem restoration as well as old-growth recruitment or beetle proofing cuts, whereas the majority of partial cuts in biodiversity set-aside areas will require retention of large-sized trees. Simplification of current scaling procedures for small wood will be necessary.

9. Industry and the provincial Small Business Forest Enterprise Program is also encouraged to develop stands in a more product-oriented fashion (i.e., value-based instead of volume-based timber management, considering certain end-products when selecting a tree for removal). Routing timber via log sort yards will facilitate this strategy.

10. When partial cutting is considered in stands with highly-valued non-timber forest products (e.g., wild mushrooms, medicinal and other botanical resources), consideration should be given to integrating biodiversity, timber and non-timber objectives.

11. Well defined landscape level plans which translate into specific stand structural objectives are critical to efficient implementation of partial cutting systems.

12. Reduce road construction costs and soil impacts by the use of long skidding. Cost allowances for long skidding should be developed in the appraisal system.

13. Pre-locate skid trails prior to timber marking to ensure marking provides for efficient and safe felling and skidding operations. Use dispersed skidding and reduce the number of skid trails.

14. Establish Wildlife Tree Patches in areas less suitable for forestry operations (e.g., severe root rot pockets, rocky outcrops, small steep areas), if those areas provide suitable habitats.

15. Reduce the cost of marking timber by marking to leave when retaining less than 50% of stems and marking to cut when cutting more than 50% of stems.

16. Faller selection is not necessarily cheaper since it reduces logging productivity and increases administration costs. Use faller selection only where fallers are trained to meet the stand level objectives and are paid to take the time to make correct choices.

17. Group selection can be laid out using geometric shapes for efficiency. These shapes can then be easily modified to fit the stand level objectives by marking to leave within the cutting units.

18. Protect preferred and acceptable advanced regeneration during the harvesting and site preparation phases.

19. Encourage the use of intermediate support systems in cable harvesting to reduce layout and road construction costs.

20. Encourage the use of forwarding trails rather than roads to position yarders in cable harvesting operations.

8.3 Extension

21. Publish a short (4-6 pages) summary version of this report (e.g., extension note or research summary). Include sufficient operational and technical silviculture information as well as ecological, economic and social rationales to facilitate development and implementation of partial cutting regimes.

22. Publish results of case studies. If case studies are conducted according to adaptive management principles, monitoring and further evaluations and possibly refinements of such trials are required. Insights gained from these trials should be communicated regularly.

23. Include material in provincial partial cutting courses such as, for example, those offered through the provincial Forestry Continuing Studies Network. If proposed partial cutting treatments are to be widely adopted in some areas (e.g., in NDT4 ecosystems scheduled for restoration cuts), consistent and high standards are desirable. Training courses and extension activities are important for achieving such standards.

24. Inform and involve the general public and stakeholder groups. Some members of the general public are well-versed on issues relating to timber and biodiversity management and should be given opportunities for involvement in ongoing initiatives.

25. Many examples exist of the successful use of partial cutting to meet biodiversity objectives in the southern interior. A compendium of examples, in a concise user-friendly format, would be useful in providing additional guidance and encouragement to agencies, industry and public.

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