Extension Note

BC Journal of Ecosystems and Management

The shelterwood silvicultural system in British Columbia – A practitioner's guide. Part 3: Operational implementation

J. Ken Day[1], Cathy Koot[2], and Alan Wiensczyk[3]

Abstract

The shelterwood silvicultural system can be used to achieve diverse management objectives. Harvesting entries during shelterwood system implementation require careful attention. Each entry can be considered a silvicultural treatment designed to modify the forest environment to accomplish specific regeneration and stand-tending objectives. Protecting the soil, the overstorey, and the regeneration become principal considerations when harvesting. At the same time, harvesting must promote an environment that will favour germination and growth of a new stand according to forest management objectives. This is the last in a three-part series of extension notes addressing the shelterwood silvicultural system in British Columbia.

KEYWORDS: *harvesting; managing risk; overstorey selection; regeneration protection; shelterwood silvicultural system.*

Contact Information

1 Manager, University of British Columbia Alex Fraser Research Forest, 72 South 7th Avenue, Williams Lake, BC V2G 4N5. Email: ken.day@ubc.ca

2 Research Co-ordinator, University of British Columbia Alex Fraser Research Forest, 72 South 7th Avenue, Williams Lake, BC V2G 4N5. Email: cathy.koot@ubc.ca

3 Extension Specialist, Ecosystems and Stand Management, FORREX Forum for Research and Extension in Natural Resources, c/o Council of Forest Industries, 400–1488 4th Avenue, Prince George, BC V2L 4Y2. Email: Alan.Wiensczyk@forrex.org

Day, J.K., C. Koot, and A. Wiensczyk. 2011. The shelterwood silvicultural system in British Columbia – A practitioner's guide. Part 3: Operational implementation. *BC Journal of Ecosystems and Management* 12(2):95–106. ***http://jem.forrex.org/index.php/jem/article/view/141/xx***

Introduction

Implementing a shelterwood partial-cutting system at an operational level involves many considerations. This extension note summarizes the experiences and collective guidance from practitioners, researchers, and the literature for foresters contemplating use of the system for the first time or applying it in a new area. Examples derive from the interior of British Columbia, but the planning and harvesting considerations should be transferable to other areas. Two other extension notes in this series (1) discuss the risks/benefits and administrative considerations of the shelterwood system, and (2) address the dynamics of forest change over time in light of disturbances and regeneration ecology.

How do you know if a shelterwood might present you with some opportunities? The following list of questions evaluate whether this form of partial cutting will help you. As an example, Table 1 summarizes considerations regarding use of a uniform shelterwood to naturally regenerate Douglas-fir in the Sub-Boreal Spruce biogeoclimatic zone (dry warm subzone Horsefly variant) (SBSdw1).

- Will a 10- to 25-year regeneration period satisfy your site-specific management objectives?
- Can you afford to leave the best trees behind on the site for 10–25 years?
- Does the terrain not require extensive excavated or bladed trails?
- Can excellent deflection be attained if cable systems must be used?
- Will you be able to access and remove trees lost to windthrow, ice, or snow damage (some is expected) throughout the rotation to prevent bark beetle outbreaks?
- Are there suitable trees (species, form, and health) to act as a seed source?
- Are the mature trees capable of reliable seed production?
- Are there local operators with experience in this form of harvesting and, if not, can you develop a range of controls to ensure the harvesting is completed as planned?

If you are trying this partial-cutting system for the first time, look for local examples and practise on a small area. Be aware of and understand the risks you are taking and that mistakes are probably inevitable. Because each implementation is a new learning experience, be creative and innovative, and bear in mind that we learn best from our mistakes. Start slowly on a forgiving area, so that the lessons you learn do not come with too much pain!

This extension note summarizes the experiences and collective guidance from practitioners, researchers, and the literature for foresters considering the implementation of the shelterwood silvicultural system.

TABLE 1. Considerations regarding the use of uniform shelterwood for regeneration of Douglas-fir in the Sub-Boreal Spruce biogeoclimatic zone (dry warm subzone Horsefly variant) (SBSdw1)[a]

Assumption 1

You are going to use shelterwood to regenerate Douglas-fir

Questions

1. Where shouldn't you use a uniform shelterwood?
    - Stand structures
        - High-density/slender trees
        - Uneven-aged stands
        - Stands that will fail if you remove 50% of trees
    - Stands with health factors
        - Frequent stem decay
        - Douglas-fir dwarf mistletoe
        - Root disease affecting overstorey trees
    - Stands that will not produce Douglas-fir seed
    - Stands where the phenotypes are not suitable
        - Epicormic branching
        - Lateral lammas growth
        - Other undesirable genetic traits
        - Where you want to invest in planting (e.g., improved stock)
    - Sites
        - Where Douglas-fir is not ecologically suitable
        - Where windthrow hazard restricts retention
        - Where root decay is an issue
        - Where you don't have a suitable seedbed and seed source
    - Management objectives
        - Where you don't want an even-aged Douglas-fir stand
    - Tenures where you cannot ensure access for a second entry
        - Roads will not remain in place

[a] Day, K., M. Waterhouse, and T. Newsome. 2008. When is it time for final removals in uniform shelterwoods? University of British Columbia, Alex Fraser Research Forest, Williams Lake, B.C. Unpublished contract report.

Management objectives

Silvicultural systems are programs of treatment formulated to fit management objectives and natural circumstances (Smith et al. 1997). Knowing the management objectives in a particular stand is critical to developing the treatment program.

Forest management objectives are generally established by landowners. Since 95% of British Columbia forests occur on Crown land, management objectives are largely established by government. Although 85% of British Columbia is covered by strategic land use plans (Forest Practices Board 2008), in most areas management objectives are not defined at the stand level. The resolutions of land use plans are at broad scales and therefore provide only limited guidance to cutblock development (Day 2006). As the Forest Practices Board (2008) pointed out, achieving a consensus-based land use plan requires that objectives be stated very broadly.

Silvicultural systems provide a conceptual framework within which managers can set clear and measurable objectives at the stand level; timing, sequence, and kind of treatments are developed to achieve the desired outcomes (Nyland 1996). Many choices can be compatible and others mutually exclusive. No single silvicultural system can achieve every demand (Weetman 1996; Kimmins 2004).

In 2009, silviculturists working across western North America were invited to describe cases where they had utilized a shelterwood silvicultural system. Input received from those practitioners indicates that shelterwood systems have been employed on several types of land ownerships to achieve a wide variety of management objectives (see Table 2).

TABLE 2. Ecological situations, land tenures, and management objectives for shelterwoods described by select practitioners in western North America

Biogeoclimatic subzone or ecological setting	Tenure/Ownership	Forest management objectives
Interior British Columbia		
SBSdw1, ICHmk3 (Williams Lake)	University of British Columbia Research Forest—Crown	Timber, pine beetle salvage, visual quality
SBSdw1 (Williams Lake)	Crown	Timber, even-aged natural regeneration
SBSwk1 (moist 08 sites) (Prince George)	Aleza Lake Research Forest	Research, education, timber
SBSdw3/mk1 transition (Fort St. James)	Small business program—Crown	Mule deer winter range, visual quality, timber
ICHdw (Salmo)	No forest tenure—Private	Timber
ICHmw2, ESSFwc1/4	Tree Farm Licence No. 23 Arrow Lakes—Crown	Caribou habitat (short and long term)
Coastal British Columbia		
CWHxm (old on variety of slopes) (Courtenay)	No forest tenure—Private	Timber, maintaining ecological attributes
CWHxm (second growth on various slopes) (Courtenay)	Forest tenure—Crown	Timber, social, environmental
CWHdm, CWHvm1 (Maple Ridge)	University of British Columbia Research Forest—Private	Education, research
CWHdm (Roberts Creek)	Crown and private	Streamside area management, visual quality, recreation
CWHdm (Roberts Creek)	Small business program—Crown	Development of structural heterogeneity
CDF (mesic site) (Texada Island)	No forest tenure—Private	Timber
United States		
Idaho wet species mix plus drier Douglas-fir	University of Idaho Research Forest	Natural regeneration of currently present and ecologically appropriate species
Montana Douglas-fir/pine grass habitat	University of Montana Research Forest	Timber, education, demonstration, research, public recreation
West-side Sierra Nevada mid-elevation mixed conifer forest	Private timberland (industrial) and University of California–Berkley Research Forest	Even-aged natural regeneration

Harvesting method design

Harvesting operations are crucial to the success of a shelterwood system. They must be carefully planned, and the harvesting contractor must be paid a sufficient amount to allow the time necessary to complete them. Harvesting has the following roles and implications to future stand development.

- Generating revenues to operate your forest management enterprise
- Generating timber products
- Increasing seedbed availability, thereby affecting regeneration establishment after harvest
- Adjusting the growing space to allow for regeneration and growth of the next crop
- Protecting the residual stand and regeneration from insects and diseases

Silviculturists who provided input to this extension note reported using a very wide variety of logging methods, as described in Table 3.

TABLE 3. Shelterwood logging methods and harvest entries used by select practitioners in western North America

Ecosystem	Overstorey species	Aggregation of overstorey	Logging methods used	No. harvest entries planned
Interior British Columbia				
SBSdw1	Douglas-fir (Interior), white/Engelmann spruce hybrid, lodgepole pine, redcedar, subalpine fir	Uniform (some areas with lower density from patched pine removal)	Feller-buncher and skidders on designated trails	2–3 depending on natural regeneration achieved
SBSdw1	Douglas-fir (Interior), lodgepole pine, white/Engelmann spruce hybrid	Uniform (70% or 50% of pre-harvest basal area)	Feller-buncher, grapple skidder, or hand falling and line skidder on designated trails	3
SBSwk1 (moist 08 sites)	white/Engelmann spruce hybrid, subalpine fir, paper birch	Uniform (~ 20 m^2/ha basal area)	Feller-buncher (hand falling of oversized), dispersed grapple skidding	2 (seed cut and removal)
SBSdw3/mk1 transition	Douglas-fir (Interior)	Uniform dispersed leave trees	Feller-buncher (hand falling of oversized), grapple skidder	1 or 2
ICHmk3	Douglas-fir (Interior), white/Engelmann spruce hybrid, lodgepole pine, redcedar	Patchy (resulting from concentrated pine salvage)	Feller-buncher and skidders on designated trails	3
ICHmw2	Engelmann spruce, western hemlock, redcedar, Douglas-fir (Interior)	Group (20–25 stems per patch), Uniform	Tower with roadside yarding and skid away using small cat/line skidder	1 in Group, 2 in Uniform
ESSFwc1/4	subalpine fir, Engelmann spruce	Group (20–25 stems per patch), Uniform	Tower with roadside yarding and skid away using small cat/line skidder	1 in Group, 2 in Uniform
IDFww (coast–interior transition)	Douglas-fir	Uniform (light and heavy removal)	Cable yarder (50–70% slopes); skidder (10–30% slopes)	1
Coastal British Columbia				
CWHxm (old on variety of slopes)	Douglas-fir, redcedar, western hemlock	Group (small and large)	Ground based at first entry, helicopter at second	1
CWHxm (second growth on variety of slopes)	redcedar	Uniform (intermediate-sized individuals)	Ground based	1
CWH	sitka spruce, Douglas-fir, redcedar	Group (small and large), Uniform	Skyline, helicopter	2 or 3

TABLE 3. (Continued)

Ecosystem	Overstorey species	Aggregation of overstorey	Logging methods used	No. harvest entries planned
CWHdm, CWHvm1 (site series 03, 04, 01, 05, 06, 07)	Douglas-fir, western hemlock, redcedar	Group (clump-gap distribution) or uniform	Hand falling, hoe-chuck/ skidder, or skyline	2–3 (seed tree and removal, or preparatory, seed tree and removal)
CWHdm	Douglas-fir, redcedar (all western hemlock removed)	Uniform	Hand falling, swing yarder rigged with running skyline	2
CDF (mesic site)	red alder	Uniform	Hand falling, skidder, processor, self-loading truck	2
United States				
Idaho wet species mix plus drier Douglas-fir	(a) redcedar, western white pine, Douglas-fir (Interior), grand fir, (b) Engelmann spruce, grand fir, subalpine fir (c) Douglas-fir (Interior), grand fir, lodgepole pine, western larch, western white pine	Uniform	Single-grip harvester and forwarder, or feller-buncher with grapple skidder, followed by prescribed under-burn or piling and burning if site preparation required	3 (unless uneven-aged)
Montana Douglas-fir/pine grass habitat	ponderosa pine, western larch, Douglas-fir (Interior)	Uniform with some grouping	Directional falling in piles with feller-buncher, full-tree skidding, delimber/processor at landing	1
West-side Sierra Nevada mid-elevation mixed conifer forest	ponderosa pine, sugar pine, incense cedar, Douglas-fir, white fir, California black oak	Uniform (10–20 m intertree spacing)	Hand falling, skidding, pile and burn tops and limbs in the woods	3 (preparatory, seed tree, and removal)

Protecting the soil

Soils are the productive potential of forests, and managers must rely on the soil resource they have inherited for future stand growth (Kimmins 1987). Partial-cutting systems require road systems and access within the stands that permits additional harvest entries over time with minimal damage to the overstorey and understorey.

Conservation of the productivity and hydrologic function of soils is a primary value and objective in British Columbia's forest policy.[1] Day (2007a) made several observations regarding soil protection that are pertinent to partial cutting in general.

- Permanent roads and landings should be carefully planned to limit their extent. Day (2007a) set a target of 4% of the net operating area to be occupied by roads and sought to reduce landings to zero through the adoption of processor/forwarder logging systems. If landings are developed, each should potentially serve 30 ha and be used for multiple cutblocks.
- Temporary access, including skid trails and roadside decking space, can remain part of the productive land base if these sites are protected by harvesting on dry or frozen soils, or by armouring trail surfaces with weight-bearing, non-merchantable logs, tops, or limbs.
- Removing tops and branches at the stump is preferable to roadside processing. The opening created on one or both sides of a road to allow for whole-tree processing and log decking negatively affects the sheltering effect of the shelterwood and increases exposure to windthrow. Processing at the stump also reduces the length, width, and weight of the load such that smaller machinery can be used and less wounding to the residual overstorey occurs.

1 Forest Planning and Practices Regulation, B.C. Reg. 14/2004, Section 5.

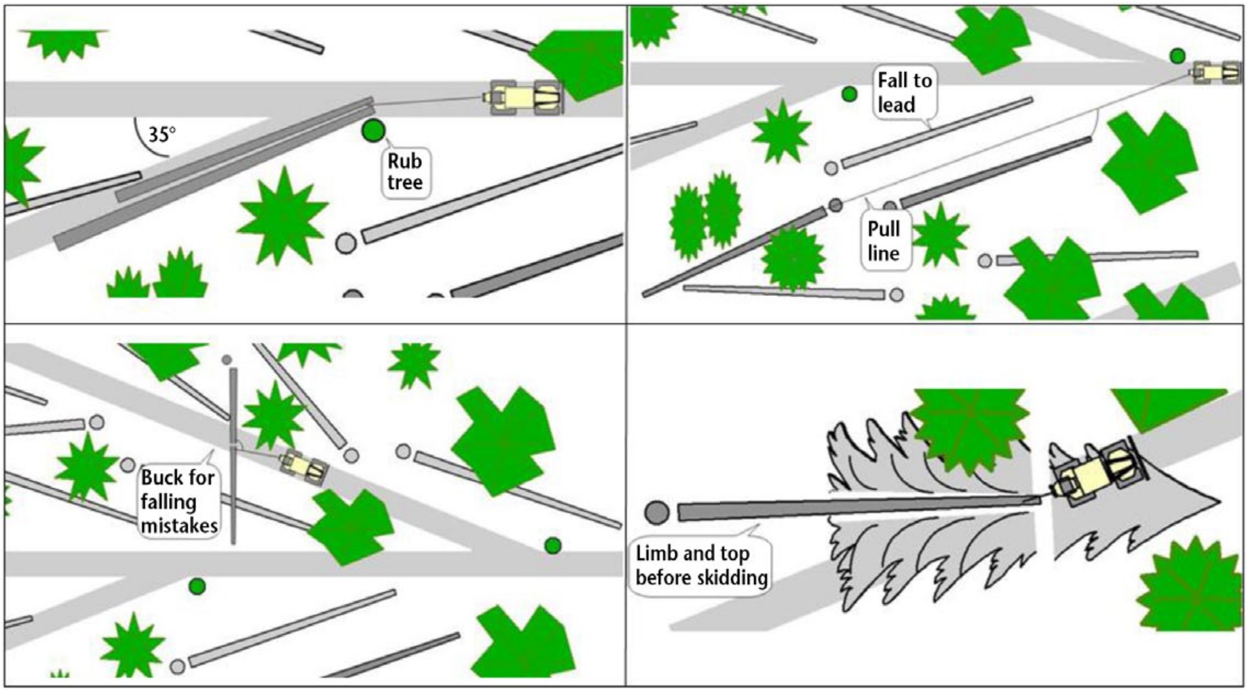

FIGURE 1. Logging practices to reduce damage to the residual stand, assuming a hand-falling/line skidder operation (from Day 1998).

Skid trail design

Skid trails and cable corridors for the whole unit need to be planned for at the start of harvest planning. This is particularly critical in group shelterwoods, where logging and regeneration occur in an aggregated fashion. Day (2007a) offered the following guidelines for skid trail design (summarized in Figure 1).

1. Aim for a target density of no more than 10% of the productive area of a stand to be occupied by trails but ensure that 100% of the block is accessible.
2. Reuse existing trails.
3. Lay out and mark trails in advance of logging to minimize trail density and reduce skidding damage (Nyland 1996).
4. Minimize trail width (e.g., less than target intertree distance at final harvest).
5. Maximize distance between trails, recognizing the implications to harvesting efficiencies and costs.
6. Design trail junctions at angles of 35° or less so as to reduce wounding of residual trees by machinery and logs.
7. Utilize ghost trails[2] to reduce the density of skid trails.
8. Retain rub trees at trail junctions, and leave these trees uncut if the next harvest entry will be in less than 10 years.
9. Plan skid trail location to avoid wet soils, and if it is necessary to cross wet ground, prepare temporary crossings at the best locations with corduroy and (or) snow.
10. Plan skid trail locations to avoid shallow soils with a high risk of soil displacement.

Selecting the overstorey

Trees retained at any harvest entry should reflect site-specific management objectives. If timber production is an objective, then the retained trees should have these attributes:

- Best vigour and form
- Least risk of windthrow, breakage, or disease, unless trees are retained for their conservation or habitat value (e.g., cavity trees)

[2] Ghost trails are those trails that are used by felling machinery but are not used for skidding or forwarding.

- Capacity to provide seed and shelter for the site
- Capacity to respond to new growing space and to grow in economic or ecological value

The proportion of overstorey retention must also consider shade-tolerance and light requirements of the species desired for regeneration.

Table 4 shows the qualitative descriptors of tree vigour in use on the University of British Columbia's Alex Fraser Research Forest. Note that Day (2007b) downgraded the vigour class of potential leave trees because of form problems, with the intent of improving the stand at each harvest entry. Form problems reduce the value of future harvests, and such trees also suffer a greater risk of loss after the initial harvest. For example, experience at the research forest has shown that epicormic branches can develop on Douglas-fir overstorey trees and

TABLE 4. Vigour classes for selection of conifer leave trees on the Alex Fraser Research Forest (Day 2007b)

		Judgement criteria					
Species	**Vigour class**	**Crown position[a]**	**Height/ diameter ratio (m/cm)**	**Crown shape**	**% Live crown**	**Bark characteristics**	**Form problems or damage**
Douglas-fir	Good	D, CD	< 0.8	Sharply pointed	> 30	Reddish, big plates, smooth light-grey upper bole	None
	Medium	CD, I	0.8–1.0	Pointed	25–30	Big plates, smooth upper bole	Fork, sweep, crook
	Poor	I, S	> 1.0	Rounded	< 25	Dark grey, rough, flat	Cracks, conk, canker
Spruce	Good	D, CD	< .08	Sharply pointed	> 40	Pink, flat plates	None
	Medium	CD, I	0.8–1.0	Pointed	30–40	Less pink, medium flakes	Fork, sweep, crook, small brooms
	Poor	I, S	> 1.0	Round to flat	< 30	Dark grey, rough, small flakes	Big cracks, canker, conk
Subalpine fir	Good	D, CD	< 0.8	Sharply pointed	> 50	Smooth, silver, resinous	None
	Medium	CD, I	0.8–1.0	Pointed	40–50	Medium smooth	Fork, sweep, crook
	Poor	S	> 1.0	Round to flat	< 40	Rough, dark plates	Big cracks, canker, conk
Redcedar[b]	Good	D, CD, I	< 0.8	Sharply pointed	Dense	Long uniform strips	None
	Medium	I	0.8–1.0	Pointed to round	Med.	Uniform strips	Fork, sweep, crook
	Poor	S	> 1.0	Flat or spike	Thin	Rough, loose fibres	Big cracks, rot, fire scars
Lodgepole pine	Good	D, CD	< 0.8	Sharply pointed	> 30	Light, small plates	None
	Medium	CD	0.8–1.0	Pointed	20–30	Medium plates	Fork, sweep, crook
	Poor	I, S	> 1.0	Rounded to flat	< 20	Loose, large plates	Cracks, canker, pitch tubes

[a] D = Dominant, CD = Codominant, I = Intermediate, S = Suppressed

[b] Because redcedar crowns generally extend well down the bole, density of foliage in the crown is a better indicator of vigour than live crown ratio.

reduce wood quality by creating knots in the outer clear wood of the high-value stems (Figure 2).

According to Oliver and Larson (1996), epicormic branches (also known as watersprouts) arise from adventitious or epicormic buds caused by alterations in the tree's environment, such as a sudden release from competition. The propensity for epicormic branching is strongly genetically controlled (B. Larson, pers. comm., 2008). Since epicormics are expressed (albeit weakly) in a closed stand, they can be selected against in the marking process. Smith et al. (1997) and Oliver and Larson (1996) also indicate that dominant trees of good vigour with full crowns are less likely to sprout epicormic branches than trees of lower vigour.

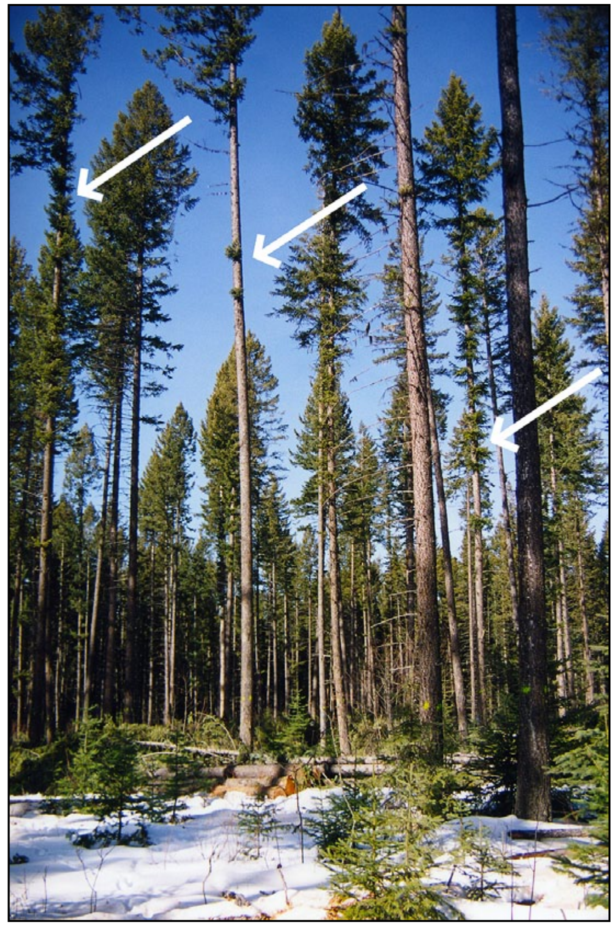

FIGURE 2. Epicormic branching on Douglas-fir 10 years after uniform shelterwood preparatory cut reduced the density to 50%. Photo taken at Alex Fraser Research Forest during a partial removal cut, when density was reduced by a further 50%.

Timber marking

Timber marking provides clear direction to fallers during harvesting and allows selection of individual trees with the greatest potential to respond positively to release. Although marking incurs a cost (e.g., \$1.21/m^3 of harvest volume in a uniform shelterwood, per Dunham 2001), it is possible to reduce falling costs by reducing the time required for fallers to make decisions, particularly if mechanical falling is employed (Ken Day, pers. obs., 2009).

Day (1998) summarized the mechanics of tree marking as follows.

- The residual stand should not be composed of "left-overs" (Fiedler 1995, p. 106) but consist of individuals selected for retention.
- Marking should be done in the fastest and least costly manner: mark-to-leave, mark-to-cut, or a combination of the two. The following protocol has been adopted at the Alex Fraser Research Forest.
  - Cut: Orange paint in a ring at breast height plus a stump mark (a short vertical stripe on the downhill side, starting below stump height and extending up above the level of the falling cut) to allow assessment following harvest.
  - Leave: Blue paint on four spots evenly spaced around the tree at breast height plus a stump mark.[3]
  - Use of two colours facilitates complex marking rules, such as "Cut all the pine except those marked with blue, and leave all other species except those marked with orange."
  - Mark trees that need to be felled in a particular direction with a vertical arrow on the side to which the tree must be felled.
- Rub trees should be designated at any place where trails turn, to protect the residual stand from skidding damage. Mark rub trees as leave trees, then re-mark for removal after skidding is finished.
- Markers must periodically ensure that the target residual basal area is being marked. This is generally done using a prism (4 or 5 m^2/ha basal area factor). Farrar (1996) recommends that 3–5% of the cut be allocated for marking wounded trees when logging is nearly complete.

[3] Trees marked-to-leave should be marked as inconspicuously as possible, since the resulting stand will have every tree marked.

Marking is challenging work and should be conducted by qualified people. Markers should be familiar with timber cruising, silviculture, and harvesting operations, particularly falling and skidding.

Harvest entries

Silviculture texts (e.g., Troup 1928; Matthews 1989; Nyland 1996; Smith et al. 1997) have described the shelterwood system as having a prescribed series of harvest entries (described below) according to European traditions. When applying the shelterwood system in British Columbia, managers are encouraged to adapt the traditional harvesting regimen such that their management objectives can be reached with the fewest number of harvest entries (see Table 5). Although silviculturists who contributed to this report used various harvest entries to achieve their objectives, the majority of those practitioners contemplated only two entries in their shelterwood system (see Table 3). Consider two primary questions before initiating a harvest entry.

1. How does this harvest entry contribute to the management objectives for the stand? Will undertaking this entry help to advance the stand into a condition that will fulfill the management intent?

TABLE 5. Considerations regarding planning cut phases of uniform shelterwood for regeneration of Douglas-fir in the SBSdw1[a]

Assumption 2

You should take two cuts over a 10-year period to establish good regeneration

Questions

1. Do you want your overstorey trees to grow larger?
2. Can you tolerate the risk of damage to overstorey during the establishment phase?
3. Are you willing to fill-plant gaps in stocking?
4. Have you had a natural disturbance that mimics a cut?
5. Can you plan the regeneration cut to coincide with a seed crop?
6. Can you guarantee a re-entry?
   - When regeneration is ready (10 years)
     - Monitor and return when regeneration is ready (by expert opinion)
   - Can you withstand the inflexibility of the return schedule?

[a] Day et al. 2008, *op. cit.* Table 1.

2. What are the trees telling us? Is the regeneration running out of growing space? Is the overstorey failing?

At each harvest entry, trees that present a hazard to the stand (e.g., those infested by bark beetle) or are at risk of dying should be removed. Cutting schedules should also be flexible, to take advantage of a good log market or an excellent seed crop.

Preparatory cut

Preparatory cuts are very similar to commercial thinnings (Smith et al. 1997) and prepare stands for heavier cutting later. Reduced competition improves the vigour of residual trees, while thinning stimulates reallocation of wood growth in overstorey trees to the boles, thereby increasing wind firmness. The initial harvest may also stimulate the decomposition of accumulated humus that might impede regeneration of the desired regeneration species. Preparatory cuts also help to stimulate seed production in the overstorey (Matthews 1994; Nyland 1996). For vigorous stands with an ample density of desirable and stable overstorey, the preparatory can be forgone.

Seed cut

The seed cut is the commencement of the regeneration process (Troup 1928; Smith et al. 1997) in that it opens up enough growing space to allow development of regeneration but retains some of the overstorey to provide shelter. The seed cut (see Table 6) should be ideally timed to coincide with a good crop of seed of the desired crop (Troup 1928; Matthews 1994; Smith et al. 1997), though this may not be necessary if seed crops occur frequently enough to assure regeneration before the site becomes occupied by other species (Matthews 1994; Smith et al. 1997).

For germination to occur, there must be sufficient seedbed available. Site preparation treatments that do not damage overstorey trees and their roots (e.g., light raking with a toothed excavator bucket) can be used to expose mineral soil covered by a heavy litter layer or debris in advance of seedfall. Rotting wood can be an excellent seedbed for some conifers (Burton et al. 2000), so treatments should aim to expose but not disturb the rotting wood already in place. A relatively small area of the forest floor need be available as a seedbed. Burton et al. (2000) reported that only about 7% of the forest floor was suitable for germination (rotting wood and mineral soil) while the remainder was covered by moss and undecomposed forest floor 2 years after summer logging. Despite this small seedbed area, regeneration has been ample on those sites (Burton et al. 2000).

TABLE 6. Considerations regarding the seed cut in a uniform shelterwood for regeneration of Douglas-fir in the SBSdw1[a]

Assumption 3

After the seed cut we have 50% or more of maximum site occupancy in the overstorey

Questions

1. Will this provide sufficient environmental (frost) protection?
   - If not, leave more
2. Will this provide a stable overstorey?
   - If not, leave more
3. [illegible]he windthrow risk high enough that you cannot remove enough to get adequate regeneration?
4. Will the stand withstand a cut of 30–50% removal (windthrow)?
5. Is your selling price advantageous?
   - If so, leave less
6. Is there sufficient seedbed?
7. Did you harvest the seed cut when there was a suitable seed crop?

[a] Day et al. 2008, *op. cit.* Table 1.

Sanitation or salvage cut

Salvage cuts remove trees that are windthrown or damaged by snow or ice, whereas sanitation cuts remove insect-infested trees or those likely to become infested (Nyland 1996; Smith et al. 1997). Day (2007a) determined whether a site will have sanitation or salvage cutting by considering the value of the damaged timber, the volume of the losses, the difficulty of recovering the losses, and the probability of the damage resulting in an expanding bark beetle outbreak.

Removal cut

Removal cuts uncover the new tree crop by removal of the overstorey (Smith et al. 1997). These cuts can occur in one entry or in a series where the regenerated stand is gradually released. Removal cuts (see Table 7) need to balance the increasing growing space requirements of the regeneration against the environmental conditions the overstorey is modifying. For example, in the uniform shelterwoods described by Waterhouse and Newsome (2006), a partial removal cut was undertaken to reduce the overstorey density by half so as to create more growing space to the regeneration but still provide it with protection from summer frost damage. That removal cut, however, destabilized the stand in the wetter site of three replicates studied, resulting in ongoing windthrow. An alternative harvesting sequence for a similar site in an operational setting might be to conduct a heavier initial seed cut, followed years later by a single removal cut. Troup (1928) recommended that removal cuts should be completed as soon as regeneration is "sufficiently well advanced," with the state of the regeneration being the chief guide toward the scheduling and intensity of the removal cut(s).

Practitioners of the shelterwood system in coastal forests indicated that on some productive sites, overstorey canopies closed overtop of regeneration, reducing growing space to the extent that regeneration of even very shade-tolerant species failed. A heavier seed cut, and (or) initiation of removal cut(s) before the overstorey canopy closed, might have provided sufficient additional growing space to maintain regeneration, but these changes to the harvest program might have made a shelterwood system impractical in the circumstances.

Few silviculturists who provided input to this report have completed the final removal cut in their shelterwoods. Scheduling the final removal is important, but there is some flexibility in timing, since regeneration growth and vigour slows down over a period of several years. A few of those polled indicated that they will not return for the final removal, but instead will allow the stand to become an irregular shelterwood having two age classes present—residual overstorey plus established and growing regeneration. Some decided

TABLE 7. Considerations regarding the removal cut in a uniform shelterwood for regeneration of Douglas-fir in the SBSdw1[a]

Assumption 4

After 10 years we have regeneration adequate to achieve the target stand

Questions

1. If your density is inadequate, will you get more by waiting?
2. Is regeneration likely to be in a frosty position after a removal cut?
   - Leave longer to grow taller, *or*
   - Consider a release cut to retain some overstorey cover
     - Where Douglas-fir is not ecologically suitable
3. If distribution is not satisfactory, would you consider fill-planting?
4. If you have adequate regeneration sooner, can you take the overstorey sooner?
5. If the overstorey is gaining substantial value, would you leave it longer?

[a] Day et al. 2008, *op. cit.* Table 1.

to retain a small portion of the overstorey after the final cut as a contribution to stand-level biodiversity.

If a stand is converted to an irregular structure through omission of the final removal, the overstorey will experience an extended period of growth while the regeneration will be suppressed. Shade-tolerant species in the understorey will be favoured, and short-lived species and damaged trees in the overstorey will likely be lost before the next harvest entry.

Protecting the overstorey and regeneration

Harvesting, if poorly planned or implemented, can undo all the good work accomplished in a shelterwood by damaging the residual overstorey trees or the regeneration or both. Many practitioners who provided input reported that co-operation among planners, logging supervisors, loggers, and regulators is extremely important to success. As the faller is ultimately the most important person in the successful implementation of a shelterwood system, it is of great importance to hire talented logging contractors.

Removal and salvage cuts can damage the regenerated stand, and this risk increases as regeneration size increases. Felled, wide-crowned overstorey trees will cause a lot of damage to the understorey. Troup (1928) shows photos of final removals in France where workers are topping the oak overstorey before felling to reduce the impact on the regeneration. Partial removal cuts described by Waterhouse and Newsome (2006) relied on large feller-bunchers to place cut trees on the trails without falling them through the regeneration. D'Anjou (2001) removed windthrow in a sanitation entry, causing some damage to regeneration except where a helicopter was used.

Directional falling is critical to protecting the overstorey and regeneration (Tesch et al. 1986). With ground-based logging the damage can be minimized by utilizing rub trees or stubs, limbing and topping in the bush, and ensuring that skid trails meet at acute angles, as depicted in Figure 2. Ensuring that trails are straight and well distributed will also help to ensure that regeneration damage is minimized. Hoe-forwarding might also be considered as an alternative to skidding, requiring fewer trails and minimizing wounding to residual trees.

With cable logging systems, overstorey and regeneration can be protected by yarding uphill with dedicated rub trees along corridors and by using increased suspension of the logs via a skyline system rigged to a back spar. Tesch et al. (1986) found that yarding across lateral slopes increased mortality of regeneration greater than 100 cm in height and that numerous corridors converging on a single landing resulted in extensive site disturbance and mortality. Minimizing cable corridor widths and corridor numbers converging on landings will minimize regeneration mortality.

Successful application of a shelterwood system can achieve land management objectives and provide excellent yield and regeneration.

Summary

Successful application of a shelterwood system can achieve land management objectives and provide excellent yield and regeneration. Shelterwoods require careful attention to harvest planning. Harvest entries act as silvicultural treatments and are designed and implemented to modify the forest environment, to realize specific regeneration and stand-tending objectives. Protection of the soil, the overstorey, and the regeneration is paramount.

Acknowledgements

Input was gratefully received from practitioners and researchers from British Columbia and some western states. They were Ross Appelgren, Phil Burton, Brian D'Anjou, Mike Jull, Mike Larock, Paul Lawson, Cameron Leitch, Frank Maus, Rainer Muenter, Teresa Newsome, Cheryl Power, Mircea Rau, Frieder Schurr, Michaela Waterhouse, and Ken Zielke. Gordon Weetman kindly provided access to his extensive library.

References

Burton P.J., D.C. Sutherland, N.M. Daintith, M.J. Waterhouse, and T.A. Newsome. 2000. Factors influencing the density of natural regeneration in uniform shelterwoods dominated by Dogulas-fir in the Sub-Boreal Spruce Zone. B.C. Ministry of Forests, Research Branch, Victoria, B.C. Working Paper No. 47.

D'Anjou, B. 2001. Effects of dispersed retention harvesting on stand structure and regeneration in a coastal mixed-conifer forest: Summary of year 6 results. B.C. Ministry of Forests, Vancouver Forest Region, Nanaimo, B.C. Forest Research Technical Report No. TR-006.

Day, J.K. 1998. Selection management of Interior Douglas-fir for mule deer winter range. MF thesis, University of British Columbia, Vancouver, B.C.

Day, K. 2006. Finding a measure of certainty through forest management planning. Branchlines 17(3):5. University of British Columbia, Faculty of Forestry, Vancouver, B.C.

_______. 2007a. Management and working plan no. 3. University of British Columbia, Alex Fraser Research Forest, Williams Lake, B.C.

_______. 2007b. Forest stewardship plan. University of British Columbia, Alex Fraser Research Forest, Williams Lake, B.C.

Dunham, M.T. 2001. Planning and layout costs II: Tree marking costs for uniform shelterwood prescriptions. Forest Engineering Research Institute of Canada, Vancouver, B.C. Advantage Report 2(34):1–4.

Farrar, R.M. 1996. Fundamentals of uneven-aged management in southern pine. In: W.K. Moser and L.A. Brennan (editors). Tall Timbers Research Station, Tallahassee, Fla. Miscellaneous Publication No. 9.

Fiedler, C.E. 1995. The basal area-maximum diameter-q (BDq) approach to regulating uneven-aged stands. In: Proceedings of uneven-aged management: Opportunities, constraints and methodologies. K.L. O'Hara (editor). University of Montana, Montana Forest and Conservation Experiment Station, Missoula, Mont. Miscellaneous Publication No. 56, pp. 94–109.

Forest Practices Board. 2008. Provincial land use planning: Which way from here? Victoria B.C. Special Report FPB/SR/34.

Kimmins, J.P. 1987. Forest ecology. Macmillan, New York, N.Y.

_______. 2004. Emulating natural disturbance: What does this mean? In: Emulating natural forest landscape disturbances: Concepts and applications. A.H. Perera, L.J. Buse, and M.G. Weber (editors). Columbia University Press, New York, N.Y. pp. 8–28.

Matthews, J.D. 1991. Silvicultural systems. Oxford University Press, New York, N.Y.

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

Oliver, C.D. and B.C. Larson. 1996. Forest stand dynamics. Updated ed. John Wiley and Sons, New York, N.Y.

Smith, D.M., B.C. Larson, M.J. Kelty, and P.M.S. Ashton. 1997. The practice of silviculture: Applied forest ecology. John Wiley and Sons, New York, N.Y.

Tesch, S.D., D.H. Lysne, J.W. Mann, and O.T. Helgerson. 1986. Damage to regeneration during shelterwood overstory removal on steep terrain: A case study. Oregon State University, Forest Research Laboratory, Corvallis, Oreg. Research Note No. 79.

Troup, R.S. 1928. Silvicultural systems. Clarendon Press, Oxford, U.K.

Waterhouse, M.J. and T. Newsome. 2006. Uniform shelterwood systems in the Sub-Boreal Spruce Zone: Update for year 15 (Phase 2). B.C. Ministry of Forests and Range, Southern Interior Forest Region, Forest Science Program, Kamloops, B.C. Extension Note No. 3.

Weetman, G.F. 1996. Are European silvicultural systems and precedents useful for British Columbia silviculture prescriptions? Canadian Forest Service and B.C. Ministry of Forests, Victoria, B.C. FRDA Report No. 239.

ARTICLE RECEIVED: March 16, 2009
ARTICLE ACCEPTED: May 12, 2011

Production of this article was funded, in part, by the British Columbia Ministry of Forests, Lands and Natural Resource Operations.

Test Your Knowledge . . .

The shelterwood silvicultural system in British Columbia – A practitioner's guide.
Part 3: Operational implementation

How well can you recall some of the main messages in the preceding Extension Note?
Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. Harvesting entries in a shelterwood system serve which function(s)?
   A) Stand tending
   B) Site preparation
   C) Protection of the stand from insects and disease
   D) Modification of an environment conducive to tree regeneration
   E) All of the above

2. The seed cut
   A) Removes the best-formed and largest trees from the overstorey
   B) Creates conditions for germination of desired species
   C) Does not benefit from pre-harvest timber marking

3. During the removal cut
   A) Directional falling is not necessary
   B) Damaging the understorey is not a concern
   C) Original skid trails or cable corridors are reused

ANSWERS

1. E; 2. B 3. C