Integrating Timber, Visual, Hydrological and Habitat Management Objectives Through Landscape

By
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Abstract

The proposed project “Integrating Timber, Visual, Hydrological and Habitat Management Objectives Through Landscape Planning” represents an interdisciplinary initiative that will use multiple scenario modelling to develop a balance between a diverse set of resource objectives at the landscape scale. By establishing defensible, technically based objectives for the three non-timber resources identified above and using an iterative approach to develop management scenarios that balance timber and non-timber values at the landscape scale, opportunities for diminishing conflict will be identified. This approach has the advantage of representing a clear process where stakeholders can objectively evaluate the short and long-term consequences of different scenarios simultaneously, and will help in the development of balanced, sustainable forest management practices.

The main objectives for the 2003-04 year were to complete stand level modelling in relation to managed and natural disturbances, to develop quantitative habitat supply models for selected vertebrates at the stand level, to develop quantitative habitat supply models for selected vertebrates at the landscape level, to finalize visual and watershed indicators, and to summarize the relationship between understory light conditions and understory productivity and composition. Two case study applications used the TASS stand model to evaluate the consequences of management options in interior dry-belt forests, and high-elevation forest with the objective of balancing timber and habitat issues relating to mule deer and mountain caribou habitat supply. The TELSA landscape model was used to explore the long-term, landscape-level conditions in the Hunters Ranges area of southern BC by assessing the consequences of management options and assumptions about natural disturbances on mountain caribou habitat supply.

The IDF stand modelling project (TASS – Tree And Stand Simulator) quantified the likely loss in timber volume increment in relation to retention stand densities, and indicates that low (<150 sph) densities will likely be necessary to maintain the desired level of production in the understory. These low residual densities will likely have a strong downward pressure on timber supply and possibly wood quality, and are in consistent with current expectations. In mountain caribou habitat, partial cutting of > 50% volume removal, along with diminished regeneration will likely be necessary to maintain the relatively open canopies that favor Bryoria (the main forage lichen for mountain caribou) colonization and growth.

Landscape modelling with TELSA on the Hunters landscape illustrates the long-term consequences of standard rotation harvesting on seral condition, and the proliferation of active roads (a harassment issue) associated with light volume removal (e.g. 20% BA removal) partial cutting. Late mature forest (e.g. > 160 yeals old) is virtually eliminated if conventional harvesting and 120 year rotations are applied. If high capability caribou habitat is to be maintained in late mature condition, special no-harvest, or limited harvest zones will need to be implemented. Similarly, although low volume removal partial cut systems maintain desirable age characteristics in mountain caribou habitat, the proliferation of active roads brought about by frequent entries may more than offset any benefits. A combination of aggregated harvesting to create large pulsed entry management units, combined with prompt road deactivation may be a viable solution.
The Landscape Project Research Team

The project team represents an established, interdisciplinary group from academia (Sheppard-UBC), the private consulting sector (Cameron-JSThrower; Huggard, Lewis, Robinson-ESSA, Walton) and the BC Forest Service (Klenner, Hamilton, Giles, MacLauchlan, Rennie, Winkler). The team represents specific individuals from each sector that have the skills, experience and commitment to participate in a project that addresses difficult, interdisciplinary issues that require broad thinking and an appreciation for diverse issues. Two First Nations clients (Bonaparte Indian Band, Little Shuswap Indian Band) have been included in the program since 2001. Because of the limited experience, facilities and training in these two client groups, analyses relating to their concerns have been conducted by Klenner and Walton. Both groups expect to, and are scheduled to continue receiving support for their participation in the project in 2003-04. Close work with WLAP staff was anticipated in the second half of the proposed project year as technical revisions are completed.

The project team has not worked in isolation since a diverse group of agency partners and collaborators support this proposal. The work has clear linkages to two large, ongoing silvicultural systems projects (Sicamous Ck. and Opax Mt. - Vyse and Arsenault) that will benefit directly from the proposed stand structure modelling and the exploration of landscape-level application of the management systems being tested at these two research sites. An agency client (WLAP - Belliveau) will be the contact for developing a future extension plan for the project, and is the recipient of stand and landscape habitat suitability modelling of mountain caribou habitat. Two other collaborators (Goudie, Polsson) provide support for the project and linkages to other initiatives at the stand modelling level.

Five agency clients representing BC Timber Sales (Lewis), Timber Supply Branch (Townsend), Water, Land and Air Ppprotection (Belliveau), Sustainable Resource management (Morgan), and Ministry of Forests, Stewardship (Peterson) support the work and the procedures being developed. These agency clients span a range of responsibility levels from operational (Lewis), regional (Belliveau, Morgan, Peterson) to branch level (Townsend), illustrating the broadly applicable nature of the work.

Introduction

The landscape project represents an interdisciplinary initiative that uses multiple scenario modelling to help identify practices that promote maintaining desired conditions at the stand and landscape scale. A balanced approach to maintaining timber and non-timber values is a key issue in the development of sustainable forest management plans and future forest products marketing. Landscape modelling of timber and habitat values is relatively well established in the literature (see Hansen et al. 1993, Li et al. 1993, Gustafson and Crow 1996, Sessions et al. 1997, Klenner et al. 2000). However, the application of these concepts to operational issues in BC is infrequent. The ability in TELSA to impose assumptions about natural disturbances to
complement management actions represents an advance towards addressing the response of timber, habitat, visual and watershed indicators under conditions frequently encountered in the interior of BC. This work is relevant to forest management in the current climate of science-based forest management and sustainable forest management, and represents the initial stages of quantifying habitat, visual and watershed indicators in much the same way that timber supply is modelled.

Our landscape modelling work to date (Klenner et al. 2000) clearly shows that some desired conditions (e.g. OGMA targets) are difficult or impossible to maintain in the face of non-equilibrium natural disturbances, regardless of the management actions used. Multiple-scenario landscape assessments can help identify unrealistic expectations, and illustrate the utility of specific stand (e.g. variable retention/partial cutting) and landscape management (e.g. aggregated harvesting) practices that favor achieving and maintaining desired conditions.

**Project Objectives: 2003-04**

Proposed Work for 2003-04. In 2003-04, the project will focus on completing much of the background technical work undertaken in the first two years of the project and working with three selected clients on specific applications. The proposal consists of the following nine components:

1. Stand-level modelling with TASS (Tree And Stand Simulator) to complete the phase 1 stand-level modelling of natural and managed disturbances
2. TELSA model testing and revisions.
3. Watershed indicators in relation to stand structure and landscape conditions.
5. Insect pests. We analyzed insect pest frequency of attack data from permanent sample plots or surveys to calibrate the natural disturbance mortality component of TASS.
6. Extend stand structure modelling to track the condition of snags and downed wood.
7. Develop quantitative stand and landscape level habitat suitability models for vertebrate indicators.
8. Understory condition and canopy light.
9. Landscape planning options in the Hunters Ranges.
10. Extension and demonstration with the Bonaparte Indian Band, the Little Shuswap Indian Band and WLAP.
**Results for Project 1: Stand Modelling**

Assessing the likely consequences of stand density on forage and timber production in dry-belt IDF stands.

Walt Klenner, I. Cameron and R. Walton

**Summary**

The following figures and tables illustrate the likely understory grass, forb and shrub and timber consequences of managing for different stand densities in ungulate winter range areas. The results are the outcome of TASS (Tree And Stand Structure) simulations using two site index values that represent responses that would likely occur on "poor" and "good" growing sites. This approach was used to illustrate the different consequences of site condition since the IDF is a complex mosaic of site conditions where tree growth is limited by numerous factors including moisture, soils, etc. We modelled the likely response by both poor and good site index stands to facilitate extrapolating the results to a range of conditions. The overall conclusion is that it is unlikely that treatments that will produce forage reflecting 50% of site potential will also produce 50% of the timber potential of that site. Lower stand densities may also lead to undesirable tree form (very deep crowns) that affect timber quality. A balance of timber and understory forage values would likely be more successful if a suitable landscape (multi-stand) context for balancing timber and forage values were pursued.
Figure 1. The merchantable volume per hectare (a) and the volume gained per ha (b) since thinning for 10 stand treatment options. The R0, R10, R76, etc. in the legend indicate the number of retention stems left after thinning. R0 indicates the clear-cut and plant with 1000 seedlings treatment, the No Cut treatment represents a stand allowed to continue to grow for an additional 100 years without thinning.
Figure 2. The effect of stand density on PACL (Percent Above Canopy Light) values. Red and yellow represent a high and moderate likelihood (respectively) of maintaining understory forage at greater than 50% of site potential.
Using a Stand Simulation Model to Estimate Arboreal Lichen Response to Partial Cutting Treatments in High Elevation Engelmann Spruce-Subalpine Fir Forests.

Doug Lewis, W. Klenner, I. Cameron and R. Walton.

Summary.

Consequences of Partial Cutting on Management of Landscapes

Large-scale use of a partial cutting systems to manage for lichen will ultimately affect management of landscapes. Assuming a constant annual cut, the use of low removal partial cuts can encroach upon undisturbed forest areas at a greater rate than under a management regime utilizing high removal systems (Crow and Gustafson 1997). Thus, the outcome of extensive use of low removal partial cuts may be larger road networks and faster rate of dispersion of early seral habitats on the landscape (Mladenoff et al. 1993, Spies et al. 1994). Increased road networks and landscape fragmentation are potential concerns to managing current threats (i.e. backcountry access and predation) on caribou (BC Ministry of WLAP 2002).

Used in a proper spatial and temporal landscape context, the use of high basal area removal partial cuts may provide greater flexibility and control in the management of human access and in spatial and temporal management of habitats. Aggregating low retention harvests may allow larger areas of forest interior to be maintained for longer periods (Gustafson and Crow 1994, 1996, Von Sacken 1998). Such protective measures may be particularly useful in already highly fragmented landscapes where further dispersion of cutblocks may increase habitat fragmentation, isolate habitats and lower habitat connectivity (Crow and Gustafson 1997). In addition, high removal partial cuts focused in already highly disturbed areas may allow managers to spatially and temporally manage large portions of the landscape to manage recovery of suitable forested habitat or spatially separate early seral habitats that attract other ungulates away from high use caribou areas.

Timber Management Objectives

From a timber management perspective, high removal partial cuts offer a better opportunity to meet timber objectives. High removal partial cuts utilize a greater amount of tree volume on the site, potentially decreasing logging costs (Mitchell 1996). Single logging entries also allow greater use of temporary roads and minimize extensive road networks for frequent access (Crow and Gustafson 1997). Both these factors can potentially minimize road
construction and maintenance costs (Bieber, 2002). High removal partial cuts may also provide
for better survival and growth of planted regeneration (Newsome et al. 2000) or release of
advanced regeneration (Messier et al. 1999) as more solar radiation reaches the forest floor and
can warm the soil (Lajzerowicz et al. 2004). Soil warming may offer better survival of favored
commercial tree species such as spruce that are less tolerant of shade (Messier et al. 2000).

Results for Project 2: TELSA revisions

Ongoing modifications to the TELSA interface and several modules (fire spread module) were
conducted by ESSA Technologies limited.

Results for Project 3: Watershed Indicators

The main initiative to develop indicators for watershed condition could not be completed by the
co-operator from UBC.

Results from work in 2002-03 were summarized in an extension note:

Schnorbus, M.A., R.D. Winkler, and Y. Alila. 2004. Modelling forest harvesting effects on
maximum daily peak flow at Upper Penticton Creek. B.C. Min. For., Res. Br., Victoria, B.C.
Exten. Note. 67.

Results for Project 4: Visual Indicators

One primary manuscript has been prepared to summarize the work on visual indicators to date
and is in the process of being reviewed at UBC.

An Approach to Modelling Visual Impacts of Natural and Managed Disturbances in Forested
Landscapes
Stephen R. J. Sheppard, Paul Picard, Walt Klenner, and Ken Fairhurst

A system of modelling predicted visual effects of forest disturbance would be a useful addition
to the developing multi-objective landscape modelling systems becoming available to resource
managers to aid planning and decision-making. The literature review on visual impacts of
natural and man-made disturbance in forested landscapes, described in this paper, highlights the
relatively small amount of scientific study on the visual impacts of disturbance types other than
clearcutting. Nonetheless, widely accepted principles of forest landscape design and extrapolation from those perception studies which have been done in western countries do provide some basis for proposing criteria which could be spatially and temporally quantified, as a first step toward visual effect or visual hazard modelling.

Initial risk/hazard matrices have been developed to attempt to predict the risk of visual impact from various disturbance types over time, at the landscape level. These initial matrices are based on literature review findings and professional assessment using team research experience and general principles, and corroborated with systematic visualizations. The visual hazard matrix presented in this paper represents an initial framework to support visual landscape modelling in the immediate future, but needs to be tested in research through systematic perception studies using systematic calibrated landscape visualizations, and perhaps in real-world experimental trials or management schemes, to be monitored over time. Current practice can contribute to emerging knowledge by documenting visual effects and public responses to such disturbances.
<table>
<thead>
<tr>
<th>Disturbance Types and Characteristics</th>
<th>Time Since Disturbance (in Years)</th>
<th>1</th>
<th>3</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>100</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fires</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wildfires</td>
<td>With an organic shape</td>
<td>Very High</td>
<td>Very High</td>
<td>Very High</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>With a geometrical shape (e.g., stepped by a road or fire break)</td>
<td>Very High</td>
<td>Very High</td>
<td>Very High</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Prescribed Burns</td>
<td>Following clearcutting with an organic shape</td>
<td>Very High</td>
<td>Very High</td>
<td>Very High</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Following clearcutting with a geometrical shape (e.g., visibly delimited by cutblock boundaries)</td>
<td>Very High</td>
<td>Very High</td>
<td>Very High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>As an understory brush fire, not affecting the inventory</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Insects and Diseases</td>
<td>Attacking and killing isolated individual trees</td>
<td>N/A</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Attacking and killing multiple adjacent trees at a time</td>
<td>With a circular/geometrical growth pattern (e.g., pine beetle)</td>
<td>Very High</td>
<td>Very High</td>
<td>Very High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>With no particular geometrical shape (e.g., a wind-driven insect)</td>
<td>Very High</td>
<td>Very High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>With the infestation visibly limited by a clear ablation range (creating horizontal lines in the landscape)</td>
<td>Very High</td>
<td>Very High</td>
<td>Very High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Isolated individual trees blown down</td>
<td>N/A</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Groups of trees blown down</td>
<td>N/A</td>
<td>Very High</td>
<td>Very High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Clearcut logging, single large blocks</td>
<td>Designed but edges not feathered</td>
<td>Very High</td>
<td>Very High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Designed and with feathered edges (designed hybrid cut)</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Not designed but with feathered edges (undesigned hybrid cut)</td>
<td>Very High</td>
<td>Very High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Not designed, and edges not feathered</td>
<td>Very High</td>
<td>Very High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Clearcut logging, multiple smaller blocks</td>
<td>Designed and with feathered edges (designated hybrid cut)</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Designed but edges not feathered</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Not designed but with feathered edges (undesigned hybrid cut)</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Not designed, and edges not feathered</td>
<td>Very High</td>
<td>Very High</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Shelterwood (2 passes)</td>
<td>N/A</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Commercial thinning (light) (2 passes)</td>
<td>N/A</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Partial cutting, with aggregated green-tree retention</td>
<td>Heavy partial cutting (leaving 30% or less of the initial stand as permanent aggregated retention)</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>Light partial cutting (leaving 30% or more of the initial stand as permanent aggregated retention)</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Partial cutting with dispersed green-tree retention</td>
<td>Reducing slope cutting or other type of partial cutting, so long as the retained trees are uniformly dispersed across the cutting area (This system is considered to be uneven-aged management because it results in 2 age classes/cohorts being created). This harvest system is considered to be leaving 30% or more of the initial stand, otherwise it is considered a shelterwood (for the purpose of this report)</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
</tr>
</tbody>
</table>

TABLE 1. Visual hazard matrix example for medium slopes (45% slope)
Results for Project 5: Insect Pests

We analysed data on the occurrence of insect pests in the Southern Interior forest region and used this data to calculate the frequency and severity of low, moderate and high severity insect attacks for western spruce budworm and Douglas-fir beetle in IDF forests, and spruce bark beetle and subalpine fir beetle in ESSF forests. These data were used to develop new insect pest modules for TASS (programmed by Ken Polsson). The final analyses conducted in March 2004 reviewed evidence for an interaction between insect attack and wildfire and this first analysis suggests there is little evidence to indicate that insect attack increases the likelihood of fire in that stand (see Figure 1 below).
Figure 1. The percent of 25 randomly chosen fires greater than 20 ha that were previously affected by a recorded insect attack with a lag of (a) 5, (b) 10, (c) 15 or (d) 20 years.
Results for Project 6: Downed wood and snags.

Modeling Deadwood in ESSF
David Huggard, March 15, 2004

Purpose
The purpose of this work was to project deadwood – snags and coarse woody debris (CWD) – for Engelmann spruce-subalpine fir (ESSF) stands, under a variety of harvest regimes, with various levels of natural disturbance agents. The projection results will mainly be used to provide habitat attribute trajectories to “populate” stands for landscape-level projections of habitat supply. Some of the projections are also used here to check how realistic the predictions appear, and which of the modeled factors have the most influence on projected deadwood.

Scenarios
A total of 240 scenarios were modeled, representing combinations of 3 main factors:
1. Species composition. Scenarios included stands with 20% subalpine fir/80% spruce; 50% of both species; and, 80% subalpine fir/20% spruce.
2. Harvest system. Simulated harvests used square patch cuts of 25m x 25m, 50m x 50m, 100m x 100m and single tree selection partial cuts. Each system was used for 20%, 40%, 60% and 80% removal in a single entry (except that 20% and 40% removal were not simulated for 100m x 100m openings, due to limitations in the live tree model). Additional runs included no harvest and 100% removal.
3. Natural disturbance agents. Runs were conducted with windthrow and 4 levels of bark beetle attack – high, medium, low and none. A fifth sets of runs used no natural disturbances (other than competition mortality of live trees, which is inherent in the live tree model).

All combinations of these factors were simulated. Details of the harvest systems and natural disturbances are reported elsewhere.

All runs started with some initial live trees present, then included 149 years prior to harvest, to produce a stand comparable to existing older ESSF stands. Harvest occurred at year 149, followed by 100 years of post-harvest simulation.

Live tree model
Production, growth and mortality of live trees were projected in TASS. Details are provided elsewhere. Information on species, size, age, location, cause of death and year of death were provided from TASS to the deadwood model for each tree dying over the simulation period. Windthrown trees were assumed to be fully downed wood (as opposed to windsnap). Beetle-killed trees were assumed to be standing at the time of death. All other mortality sources (e.g., suppression), were assumed to produce 70% standing dead trees and 30% downed trees. (The downed trees would occur because the proximate cause of death for many suppressed trees is snow damage).

Deadwood model description
The deadwood model tracks snags and CWD from the death of the live tree through to the disappearance of the deadwood as a structure when it becomes “duff”. Trees that die are followed as individual structures through a series of snag and log decay classes. Decay classes
follow Thomas (1979), and are used for their relevance to wildlife that use deadwood structures. The characteristics of different snag and CWD decay classes are described in Table 1.

### Table 1. Characteristics of decay classes of snags and CWD (following Thomas 1979)

<table>
<thead>
<tr>
<th>Snag class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Recently dead; bark intact or cracked; at least some fine branches present</td>
</tr>
<tr>
<td>4</td>
<td>Loosing branches; 99-50% of bark present</td>
</tr>
<tr>
<td>5</td>
<td>Most branches lost; &lt;50% bark present; wood still mostly hard</td>
</tr>
<tr>
<td>6+</td>
<td>Bark and branches lost; wood mostly or all soft</td>
</tr>
<tr>
<td>[duff]</td>
<td>Remaining unbroken part of snag decays into separate fragments of soft wood</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Log class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fresh wood; bark and at least some fine branches present</td>
</tr>
<tr>
<td>2</td>
<td>Fine branches and some larger branches lost; bark all present</td>
</tr>
<tr>
<td>3</td>
<td>Branches mostly lost; bark cracked or being lost; wood still hard</td>
</tr>
<tr>
<td>4</td>
<td>Wood soft; bark and branches mainly lost; log still has vertical sides</td>
</tr>
<tr>
<td>[duff]</td>
<td>Log has collapsed, sides less than vertical; wood broken into soft fragments</td>
</tr>
</tbody>
</table>

Live trees enter the deadwood model as class 3 snags if they die standing, or as class 1 logs if they fall at death. Deadwood structures can undergo 4 kinds of changes: 1. Snag fall, 2. Snag fragmentation (producing a log and a shorter snag), 3. Snag decay (to the next decay class, or directly to duff for class 6+ snags), 4. CWD decay (to the next decay class, or to duff for class 4 logs). These processes are illustrated in Fig. 1. All processes are stochastic, affecting the individually-tracked snags and logs with probabilities determined by the individual’s time since death, species and size. Fall, fragmentation and decay probabilities can also be modified for different site types within a stand, or positions relative to edges, but these factors were not used in the current simulations (because the entire simulated site was assumed to be mesic, and there is little evidence that fall and decay rates – unlike mortality rates – are affected by edge position). Because the deadwood model has a stochastic component, each run was repeated 10 times and an average value of each summary variable presented. (But note that the dead tree inputs from TASS were the same for each iteration of a given scenario).
Fig. 1. Decay stages and deadwood processes in the model. Live tree growth and mortality are handled outside the deadwood model. “Frag’n” = fragmentation.

The effects of management activities on deadwood are modeled with a series of rules, specifying the probability of an existing deadwood structure being retained, destroyed or modified (e.g., a snag fallen and left on site), and the amount, species, size, decay class and spatial distribution of new deadwood inputs from the activity (e.g., logging residue or thinning slash). The management rules can be based on species, decay class and size of deadwood, and also on height of snags to model retention of safe versus dangerous snags. The current simulations used the following rules at harvest:

1. Snags >5m tall were fallen if they were within one tree-height of a harvested area.
2. Snags <5m tall were retained, except 10% of class 5 and 30% of class 6 snags, representing damage during harvesting.
3. 70% of fallen class 3 snags, 40% of fallen class 4 and 10% of fallen class 5 snags were removed, simulating skidding of these potentially useable stems to landings. The rest of the fallen snags were left on site as CWD.
4. 30% of existing class 1 CWD, 80% of class 2, 70% of class 3 and 20% of class 4 in harvested areas was retained. The rest was assumed to be either skidded to landings (class 1 and 2), or destroyed during harvesting (class 3 and 4).
5. 100m$^3$/ha of additional CWD was created in harvested areas, equally divided between classes 1, 2 and 3, and representing a range of sizes (based on post-harvest data from Sicamous Creek). This additional CWD was assigned to the 2 species in proportion to their live tree percentages. The total volume was reduced proportionally in the partial cuts (e.g., the 20% removal harvest only created 20m$^3$/ha additional CWD).

Deadwood parameters

Fall, fragmentation and decay parameters for deadwood were based on a combination of results from Sicamous Creek and a literature review from other similar sites. There is wide variation in these parameters between sites and between the different species. Because the simulations were being patterned on the stands at Sicamous Creek, deadwood parameters from that site were emphasized where there was large site-to-site variability. Sicamous Creek tends to have lower fall rates, and longer decay times than several other high-elevation sites, probably reflecting the infrequent occurrence of warm weather. Because there are no clear, consistent differences between parameters for subalpine fir and spruce, the same deadwood parameters were used for each. The deadwood model can accommodate quite complex shapes of fall and decay functions, but there is little empirical information to support anything more complex than the curves shown below.

The values shown are for 40cm dbh snags or 40cm diameter logs. Based on the literature, fall and decay rates scale in direct inverse proportion to diameter. For example, the fall rate of 20cm dbh snags would be twice as fast as that shown for 40cm snags – 50% of 20cm snags would have fallen by age 24, compared to age 48 for 40cm snags. Smaller snags similarly pass through snag and CWD decay stages faster. Logs shorter than 2m also experience increasing decay rates with shorter length.
Fig. 2. Proportion of snags still standing as a function of years since tree death, for 40cm dbh snags. Fall rates scale in inverse proportion to dbh.

Fig. 3. Proportion of standing snags in each of 4 decay classes as a function of years since death, for 40cm snags. Decay rates scale in inverse proportion to dbh. Proportions add to 1 in any given year, until age 50, when some class 6+ snags begin to decay into “duff”, which is not tracked.

Fig. 4. Proportion of logs in each of 4 decay classes as a function of years since tree death, for 40cm diameter logs. Decay rates scale inversely with dbh. Proportions add to 1 in any year, until age 50, when some class 4 logs begin to decay into class 5 logs or “duff”, which are not tracked.
Standing snags can also fragment, or break off part of the bole. This happens with a probability of 1.6%/yr for class 3 snags, 2%/yr for class 4, 2.5%/yr for class 5 and 10%/yr for class 6+. These values do not change with changing dbh (because the fragmentation is happening at various diameters of the stem, and there is no empirical information on how fragmentation would change with basal diameter).

Deadwood summary variables

Many deadwood variables were summarized in these simulations, for each species separately and for the 2 species combined:
- snag density (/ha) overall, by decay class, by size class (7.5-20cm dbh, 20-30cm, 30-40cm, 40-50cm, 50-70cm and >70cm) and by decay x size class
- snag basal area (m$^2$/ha) overall and by decay class
- the standard deviation of density (/ha) of snags >15cm dbh, using 20m x 20m cells
- the average distance (m) between a snag and its nearest neighbour
- CWD volume (m$^3$/ha) overall, by decay class and by size class
- CWD density (number of pieces/ha) overall
- the standard deviation of CWD volume (m$^3$/ha), using 20m x 20m cells
- the average distance (m) from a point to the nearest log
- the density (/ha) of logs projecting >0.5m, >1m and >2m above the ground (due to piling of overlapping, non-decayed logs)

A separate file for each simulation records these values every 10 years. Figures were also plotted for a few major variables for a subset of runs.

Graphical representations of a selected subset of simulations were also produced, for simulation years 0, 50, 100, 149 (pre-harvest), 151 (post-harvest), 170, 190, 210, 230 and 250. The latter 5 times represent 21, 41, 61, 81 and 101 years after harvest. These figures represent “aerial” views of the snags and CWD on the simulation scales, plotted in position and to scale, except that snags (seen from “above” as a circle) are exaggerated 8-fold. Colours grading from bright green to red represent the 4 decay stages of snags and CWD. Snags with broken tops are shown with a central black dot, the size of which indicates the diameter at the point of breakage (also exaggerated 8-fold).

Output and results

Attribute trajectory files

Summary variables every 10 years for the 240 runs are provided in the 240 separate comma-spaced text files, with the same run name as used in TASS. Values could be interpolated between the 10 year intervals if needed, except across the harvest events at year 149.

Figures of some trajectories, and general interpretations

Figures summarizing 6 main snag variables and 6 main CWD variables are presented in the PowerPoint file “Deadwood graphs Mar 2004.ppt”. Results are shown for 20% subalpine fir and 80% subalpine fir runs, for 25m x 25m, 50m x 50m and single tree selection harvesting at all removal levels. This is a total of 28 runs (with one PowerPoint slide for snags and one for CWD for each run). Each graph has 3 lines, representing 3 disturbance levels: windthrow and high
insects, windthrow and low insects and no windthrow or insects. These particular runs were chosen for plotting to allow comparisons of low versus high fir stands, 2 opening sizes and single tree selection, different levels of removal, and the range of natural disturbances.

Some prominent patterns in these projections include:

- The classical “U-shape” is very prominent in snag numbers in the first 150 years, as snags in the initial old stand fall and are eventually replaced by high densities of trees dying from suppression. In the absence of disturbances, however, these new snags are all small, so that no snags >30cm dbh are produced, and snag basal area bottoms out at low levels after the initial snags fall.

- Because CWD is expressed as volume (not density), it does not show the U-shape. In the absence of natural disturbances or harvesting, CWD volumes bottom out much lower than the initial levels.

- With any harvesting, the recovery of snag density is truncated at harvest, while CWD volumes increase because of logging waste. The dominance of this harvesting effect increases with increasing percent removal.

- Patch size, across the scales examined – 50m x 50m, 25m x 25m and single tree selection – is largely irrelevant. For deadwood, the main direct effect of patch size is falling of dangerous snags along the edges of harvest areas. With these small openings, most snags over 5m are within the edge zone in any case. In reality, opening size could have substantial indirect effects on deadwood production, including effects of wind fetch and tree contact on windthrow rates, and effects of light and openness on susceptibility to beetles. These effects may not be captured in current TASS mortality algorithms.

- The high insect runs show 3 outbreaks in 20% removal scenarios, 2 outbreaks with 40% removal, 1 with 60% removal, and none in 80% removal. This is somewhat unexpected, and may be an artefact of the TASS beetle algorithm, in which outbreak probability is based on density of suitable trees (averaged over the whole stand, rather than just in the residual trees?)

- The level of disturbance becomes a dominant effect after 150 years, especially for snags. The differences between disturbance levels are most pronounced for large snags, which also leads to substantial differences in volumes of CWD.

- Low levels of insects have a much less pronounced effect on snag densities, but do produce some snags >30cm, versus none in runs with no natural disturbance. As a result, there is some increase in CWD volume with low levels of insects.

- At higher percentage removal, the trajectories of the various deadwood elements converge among the different disturbance levels. In other words, no natural disturbance versus high levels makes little difference at 80% removal.

- The runs with 20% removal (or none) and high levels of insects are the only ones that get back near original deadwood conditions by year 250. Even then, CWD volumes remain lower than observed at Sicamous. I think that the reduced CWD mainly reflects a lack of very large trees being produced in TASS. These very large trees (say, >50cm dbh) have a disproportionate effect on CWD volumes, because they are larger to start with, but also decay at a slower rate.

- The runs with 80% subalpine fir seemed to produce more insect outbreaks at high insect levels than stands with 20% fir. This produces a more “jagged” trajectory for the snags. Overall, however, the trajectories for the various deadwood elements were broadly similar between 20% and 80% fir at a given disturbance rate and harvest type. In part, this reflects the
same deadwood parameters used for the 2 species, but it must also indicate that the growth and mortality rates of the 2 species are not extremely different in TASS.

Graphical views

Graphical “aerial” views are provided in the PowerPoint file “Deadwood pictures Mar 2004.ppt”, for the 20% subalpine fir, 25m x 25m, 100m x 100m and single tree selection runs at all removal levels, with 4 levels of natural disturbances (windthrow and high, low and no insects, and no windthrow or insects). Each slide in the PowerPoint file shows the images at 10 time periods for a single run. [Note on printing these images: Set the “fit to page” option, as the bottom figures extend beyond the PowerPoint slide, and this cannot be fixed easily in PowerPoint. Also, setting the colour saturation or intensity to “high” on colour printers will make the relatively thin lines of the to-scale logs more visible].

Results for Project 7: HIS Models for TASS and TELSA.

Habitat Algorithms for TASS and TELSA
David Huggard, March 15, 2004

Purpose

The purpose of this work was to develop models to predict habitat suitability for a range of vertebrates. The models are intended to “populate” stands with projected habitat suitabilities in TELSA, a landscape-level simulation model that includes harvesting and natural disturbances. This will allow these species to be used as indicators of biological responses to alternative scenarios for managing landscapes.

The habitat models are primarily based on stand-level habitat elements, such as live trees, snags, cover layers, etc. The projection of these habitat elements is driven by live tree projections using TASS, along with additional models to project snags and coarse woody debris after trees die in TASS, shrub and other understory vegetation based on ground-level light tracked by TASS, and a variety of other derived habitat elements. A secondary aspect of the habitat models was to incorporate the effects of local landscape-level features, such as edges, patch isolation or roads. However, the models were not intended to include larger scale processes, such as aggregating suitable stands into home ranges, dispersal, connectivity, or population processes. Where these are important, they will be handled separately in TELSA.

“Suitability” versus “capability”

The models are meant to predict habitat “suitability”, rather than “capability”. “Capability” is determined by intrinsic features of an area, such as elevation, slope, aspect, and biogeoclimatic zone, which determine the maximum density of a species in optimal stands. “Suitability” reflects what proportion of the maximum capability is actually attained by a particular stand at a given time, based on its habitat features and perhaps also its local landscape context. For some of the species included in this work, I assume that capability has been mapped already, because of large amounts of effort that have been spent on these species (e.g., mule deer, mountain caribou). For others, simple capability factors based on BEC units are suggested, along with the more developed models of suitability.
**HSI approach**

The modeling uses a “habitat suitability index”, or HSI, approach. An HSI provides a suitability score for a particular area on a 0-1 scale. 0 is assumed to mean the animal will not occur there, while 1 indicates optimal conditions. However, the biological meaning of the scale itself is fuzzy. The way HSI models are developed, the score does not necessarily have a linear relationship with predicted density, probability of occurrence, probability of persistence, productivity or any other particular biological measure of habitat suitability. Instead, the HSI score is just meant as a relative indicator of habitat quality. For this reason, HSI modeling should be used primarily as a “heuristic” device, meant to give an idea of how different management options might affect a range of species, rather than as a rigorous model that quantitatively predicts how well each species will do.

Modeling habitat relationships with an HSI approach is based on a loose process of quantifying relationships found in previous studies, rather than rigorous empirical modeling of a particular dataset. The advantage is that this allows a wide body of experience to be (loosely) incorporated into the model. This results in a mathematical description of “expert opinion” about the needs of the species. The main disadvantage is that, without testing the models with independent data, it is impossible to know how closely this expert vision corresponds to the actual distribution, abundance, productivity, etc. of the species. The risk is that this process just captures an idealized view of a species. The actual creature may differ substantially. (The actual creature will typically show more flexibility and unpredictability than the idealized version). This reinforces the need to treat untested HSI predictions only as idealized indicators of species’ responses in larger landscape models, not as actual knowledge about exactly how the species will respond to particular conditions.

**Mathematical forms of relationships**

The original HSI models used simple relationships between habitat attributes and suitability, usually represented by 1-3 straight linear segments. This simple form was used because the HSI scores were intended to be calculated by hand. Because we now implement the models on computers, many of the relationships in this work use continuous non-linear functions, particularly the Weibull function. There is nothing particularly biological about this function – it just happens to have a sigmoidal-type form that makes it convenient for expressing the expected shape of many habitat relationships. The only advantage over simple linear relationships is that the non-linear functions do not produce artificially sharp changes in relationships at particular values (e.g., with straight line segments, a change from 20 to 25 snags may have no effect, while a change from 25 to 30 snags does have an effect).

Again, the non-linear functions were not statistically fit to particular datasets. They were generated by determining a few approximate values along the curve from the literature, then finding parameters that produced an appropriate curve. The parameters used in the curves, or the shape of the curves themselves, could easily be modified if other people expect different relationships.

Typical HSI models often rely on a simple mathematical transformation to try to capture interactions among individual elements. For example, a quadratic mean of two functions might be used to represent substitutibility of resources. This approach has always seemed fairly arbitrary to me. In this work, I’ve tried to directly specify any such interactions as part of developing the suitability functions themselves. This might include using weighted means of two or more variables, or having the value of one variable modify a co-efficient in the function
for another variable to capture the form of the interaction that I expect from the literature. For the most part, however, there is very little empirical information on even simple two-way interactions of habitat variables.

Because equations do not have any intuitive meaning for most people, I’ve presented graphs of the non-linear relationships and any interactions included in the HSI models.

**Scaling the HSI score**

The reports for each species develop the individual components of the model (e.g., the relationships with individual habitat elements, and simple interactions). They then suggest how to combine the components into an overall score. Often the individual components were designed so that they can simply be multiplied together for a final score. However, the distribution of scores resulting from this procedure is unknown, until the models have actually been applied to a range of stands. Ideally, the scores would be well distributed between 0 and 1, to meet their heuristic role as a general index of the range of habitat suitability. Most likely, however, when the models are actually applied, they will produce a poor distribution. For example, there may be a few stands near 1, and many at very low values. This would be most likely where there are many components – one of them is bound to have a low suitability score, dragging down the multiplicative combined score. In these cases with poor distributions of scores, a transformation should be applied that spreads out the scores across a more useful range. In the example, a square- or cube-root transformation might be appropriate. The exact nature of the appropriate transformation depends on the distribution of scores when the model is applied. Therefore, it is just indicated in the model descriptions as “F(…)” around the equation where the components are combined, as a reminder that this transformation step still needs to be done after the models are applied to a range of stands.

**Species and study area**

The models are developed for 6 species, which are either of particular interest, or are intended to represent different habitat features: 1. Pileated woodpeckers, 2. Pine marten, 3. Red-backed voles, 4. Microtus voles (meadow + long-tailed), 5. Mule deer, 6. Mountain caribou. Again, as heuristics, the model output should not be over-interpreted as a direct prediction of the abundance, productivity, etc. of the actual organisms. The models were developed for the specific study area in the Hunter’s Range on the west side of the Monashee Mountains. This includes mainly ESSF and ICH stands. For some of the species, different relationships might be expected in drier low-elevation stands, or stands dominated by pine.

**Use of literature**

None of the reports contains a long general literature review, because this has already been done many times for most of these species. Additionally, the scope of this work did not allow time to assemble the entire body of literature on each species, particularly those where most of this is “grey literature” (particularly mule deer and mountain caribou). Instead, short comments are made on a subset of published papers about the species. The focus was on quantitative information directly related to relationships with habitat elements and local landscape measures. The models are also compared to other existing HSI models, where these were easily available.

**Results for Project 8:** Understory condition and canopy light.
Understory - overstory relationships in wetter ecosystems of British Columbia: a review of literature (P. Bartemucci)

Summary.

The report summarizes relationships between overstory variables and understory plant responses in the cooler and wetter ecosystems of British Columbia. Ecosystems include coastal temperate, interior cedar-hemlock, subalpine, sub-boreal and boreal forest types. Information presented in this report was gathered from an extensive review of literature. Most of the information came from studies undertaken in western North America, chiefly the Pacific Northwest, but studies from analogous ecosystems in other parts of North America and the world were included for certain ecosystem types. Overstory influences on understory vegetation dynamics are discussed in un-harvested forests, in variable retention silvicultural systems and in clearcut systems. Quantitative relationships in which overstory variables were correlated with understory responses were highlighted.

Results for Project 9: Landscape planning

Landscape modelling with TELSA on the Hunters landscape illustrates the long-term consequences of standard rotation harvesting on seral condition, and the proliferation of active roads (a harassment issue) associated with light volume removal (e.g. 20% BA removal) partial cutting. Late mature forest (e.g. > 160 years old) is virtually eliminated if conventional harvesting and 120 year rotations are applied. If high capability caribou habitat is to be maintained in late mature condition, special no-harvest, or limited harvest zones will need to be implemented. Similarly, although low volume removal partial cut systems maintain desirable age characteristics in mountain caribou habitat, the proliferation of active roads brought about by frequent entries may more than offset any benefits. A combination of aggregated harvesting to create large pulsed entry management units, combined with prompt road deactivation may be a viable solution. Some examples of results are illustrated below:
Figure 1. The amount of mature and old forest in relation to natural disturbance assumptions: NF= no fire, 25% HF = fires at 25% of their historic levels, 100%HF = fire at 100% of recent historic levels.

Figure 2. The effect of the rate of harvest (50, 100 and 150,000 m$^3$/yr.) on the amount of mature and old forest.
Figure 3. The effect of the type of harvest (light volume 20% removal Partial Cutting, Small [5-30 ha] ClearCuts, Large [500-1000 ha] ClearCuts) on the amount of active roads.

Figure 4. The effect of deactivation rate (e.g. 15/3 = 15 years to deactivate primary roads and 3 years to deactivate secondary roads) on the amount of active roads in relation to type of harvesting.
Extension and Demonstration of Results

Extension work, although planned to be a modest undertaking in 2004-05, proved to be a disappointment. Work with the two First Nations clients had to be cancelled since I could not reach an agreement with the two groups about the nature of their efforts or the objectives of their work. The Water, Land and Air Protection client also declined to undertake close work with the stand or landscape modelling of mountain caribou habitat supply. Co-operative work with Opax and Sicamous silviculture systems clients was a success and remains on schedule.

Several factors likely contributed to the diminished interest in the landscape planning project. The arrival of new FRPA legislation has changed the regulatory “landscape” and there is questionable appetite (not for lack of trying on the research side) amongst potential agency clients for implementing new approaches to landscape management. The tools (TASS and TELSA) are available, considerable expertise resides with the integrated landscape planning team members, but operational applications remain a challenge as the rules, procedures and activities associated with forest management planning are clarified under new FRPA legislation.

Literature Cited