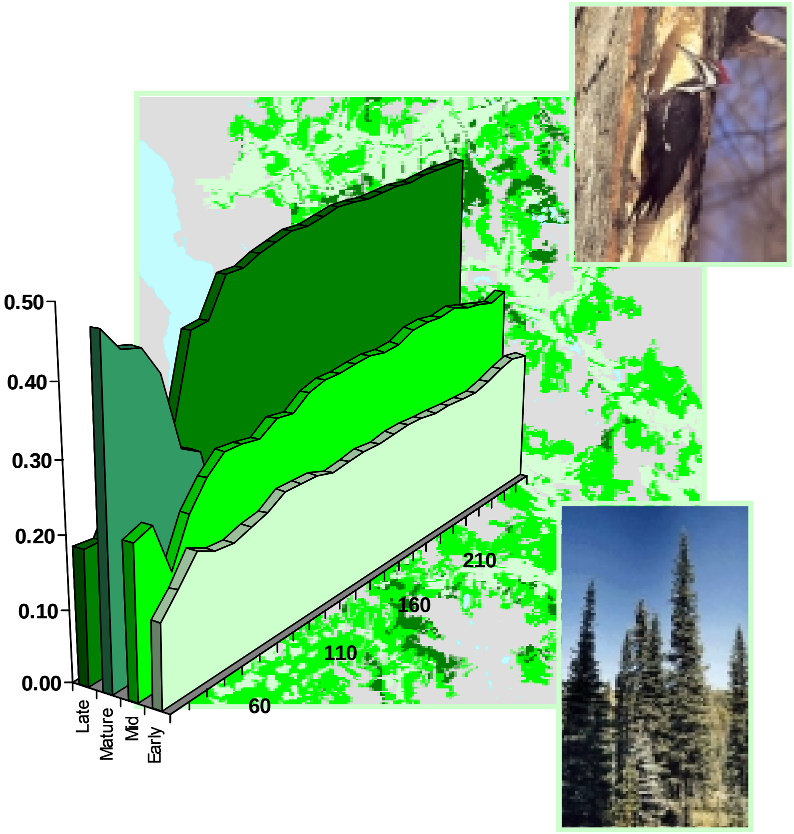
# Habitat Supply Modelling for the Arrow Timber Supply Area



Prepared for:
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31 March 2003

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# Executive Summary

Projecting habitat supply for wildlife over a forest planning horizon is a significant challenge for resource management in British Columbia. We used existing tools and data to model the supply of important habitat elements, and habitat for specific wildlife species, over a 250-year planning horizon on the Arrow Timber Supply Area (TSA).

We used the harvest schedule associated with a spatial timber supply analysis of the Arrow TSA as the landscape driver of disturbance on the timber harvesting land base. We developed conceptual models, stratified by biogeoclimatic subzone, for wildlife trees (>30 cm dbh), downed wood, hardwood composition and shrub cover that described the expected dynamics of these elements following both natural disturbances (stand-replacing fires) and forest harvest events. We then used data collected on the Arrow TSA and other data available in the literature to set parameters for the conceptual models. We also developed habitat suitability index models for pileated woodpeckers and mountain caribou that were based on the habitat elements we had modelled. We used Simfor 3.0 as a modelling environment.

Our habitat supply projections suggested that stands dominated by relatively low densities of wildlife trees, low volumes of downed wood and low shrub cover will increase over the next 250 years, with most of the changes coming in the next 100 years as late-seral stands are converted to shorter-rotation stands. Hardwoods are expected to be largely absent from the canopy layer in 160 years. High quality habitat for pileated woodpeckers and mountain caribou is also expected to decline.

The aspatial distribution of seral stages and, hence, the distribution and abundance of habitat elements in supply projections was sensitive to the inclusion of inoperable forest. Continuous aging of inoperable but productive forest generated large areas of late seral conditions.

The analysis was associated with a number of limitations: there were significant gaps in data used to set parameters for conceptual models; the analysis was restricted to the productive forest portion of the Arrow TSA; the spatial arrangement of habitat elements was not considered in projections; and no thresholds or benchmarks were available to gauge the adequacy of habitat supply.

Despite limitations, this project demonstrated a practical approach to modelling habitat supply based on existing tools and data.

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## Acknowledgements

We thank R. Wells and A. Moy for conceptual and technical support related to modelling habitat elements with Simfor. Vanessa Craig helped to develop downed wood models. Suzanne Simard provided important information regarding the dynamics of hardwoods in natural and harvested stands. We thank Mike Fenger, Brian Nyberg, Andy MacKinnon, Evelyn Hamilton, Dave Clark, George Richardson, Tory Stevens and Calvin Tolkamp for helpful comments on our methodology and results.

# Introduction

## Background

One of the principal challenges of land management in British Columbia is developing methods to quantify and forecast the supply of habitat for wildlife over planning horizons in managed forests. Spatial timber supply analyses (*e.g.*, Timberline 2002) provide schedules of both the time and location of harvest events, along with growth and yield forecasts for different forest types, under different management constraints. There is an obvious parallel between the process of forecasting forest conditions and the forecasting of habitat for wildlife.

The goal of this project was to develop a method to forecast habitat supply that could be used to indicate any shortfalls expected during a planning period for forest management. We concentrated on adapting existing tools and data to develop a method that could be applied easily to different areas.

This project is one of two provincial habitat supply modelling pilot projects conducted on Tree Farm Licence (TFL) 14 (Wilson et al. 2002) and on the Arrow Timber Supply Area (TSA; Hamilton et al. 2003). This report presents the results of the Arrow TSA pilot project.

## Objectives

The objectives of this project were to:

1) Develop and test a method for conducting habitat supply modelling on the Arrow TSA
2) Project the supply of important habitat elements over the planning horizon
3) Relate the supply of important habitat elements to habitat for selected wildlife species

# Methods

## Study Area

The study area for this project was the Arrow Timber Supply Area located in the southwestern corner of the Kootenay Region (Figure 1).

## Sources

### *Arrow Criteria and Indicators*

We chose habitat elements to model on the basis of the Arrow IFPA's criteria and indicators for sustainable forest management. Specifically, we modelled elements associated with Criterion 1 (maintenance of biological richness), Indicator 2 (habitat elements). That is, the amount, distribution and heterogeneity of habitat elements and landscape structure important to sustain biological richness. The elements include: seral stage, riparian areas, dead and dying trees (here restricted to snags >30 cm dbh), downed wood, hardwoods and shrubs.

### *Arrow IFPA Spatial Timber Supply Analysis*

Harvest scheduling for the habitat supply analysis was based on the Arrow IFPA's spatial timber supply analysis (Timberline 2002). The analysis was considered "spatial" because, unlike analyses used in Timber Supply Reviews (TSR), the location of stands (Timber Unit Mapping or TUMs) was spatially referenced in a Geographic Information System (GIS). The harvest schedule was based on growth and yield projections of a number of stand types (analysis units) and harvesting constraints (*e.g.*, Kootenay Boundary Higher Level Plan Order). The time horizon of the schedule was 250 years from present.

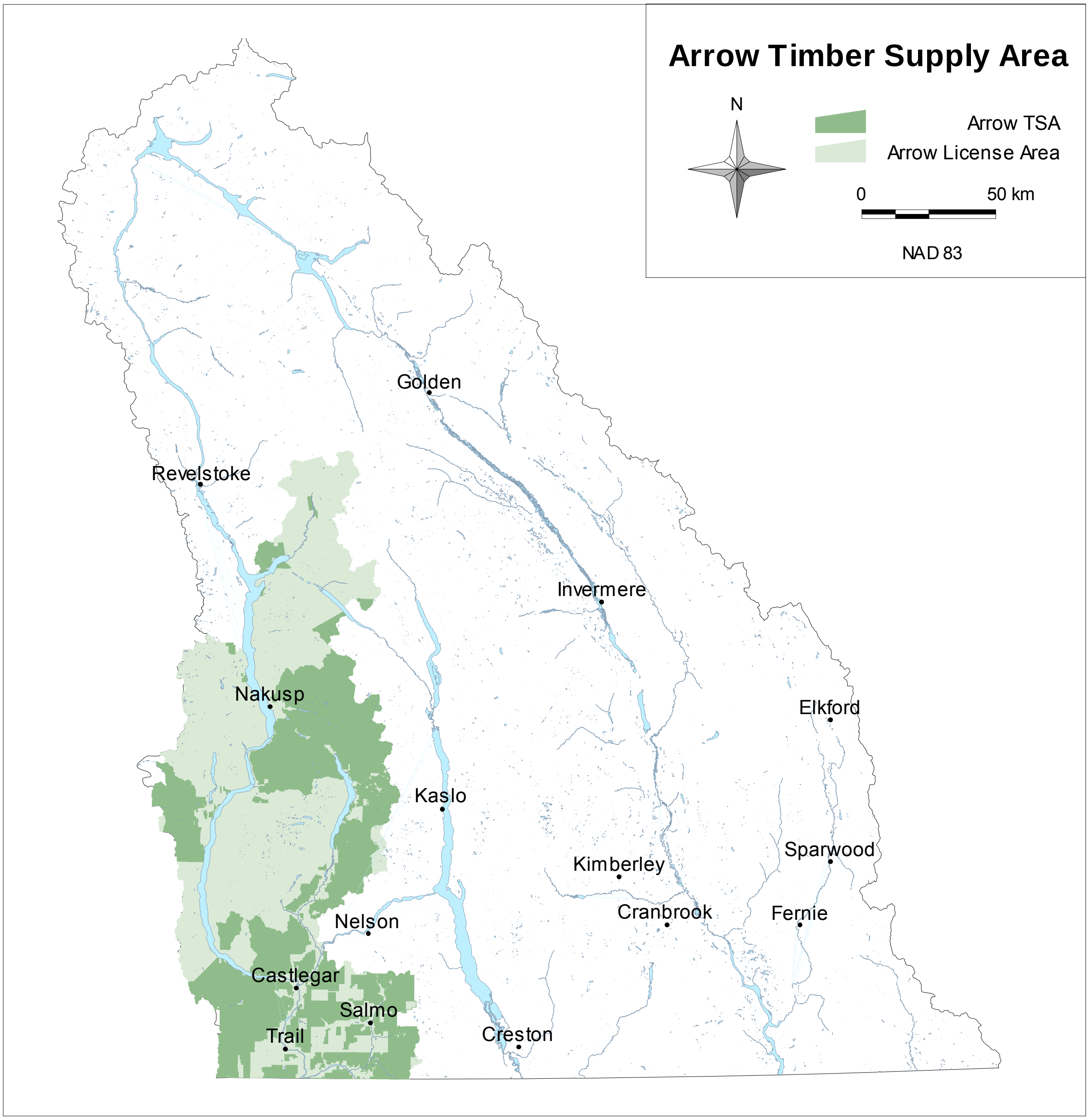

**Figure 1.** Location of the Arrow Timber Supply Area (TSA) in the Kootenay Region.

## Modelling

### *Habitat Elements*

Our general approach to modelling the supply of habitat elements over time was to first develop a conceptual model that described the expected dynamics of the habitat element from the time of disturbance (fire for natural stands and clearcut for managed stands) to a late-seral steady state (Appendix I). Separate conceptual models were developed for common biogeoclimatic subzones (ESSFwc, ICHdw, ICHmw2, ICHwk; Meidinger and Pojar 1991) found in the timber harvesting land base (THLB). We reviewed data collected during projects conducted on the Arrow TSA and other available data in the literature and estimated parameters for the conceptual models.

We used return intervals from the Biodiversity Guidebook (BC Ministry of Environment 1995) to estimate seral stage distributions expected under a natural disturbance regime. These distributions were used to derive natural disturbance benchmarks for different habitat elements.

We restricted our modelling to the THLB, which was the area disturbed by the harvest schedule (approximately 200,000 ha). This constituted about half of the area of productive forest on the Arrow TSA (Timberline 2002).

We used SIMFOR (Wells and Moy 2002) as a modelling environment. Simfor generates raster-based maps of future forest conditions based on a disturbance schedule, map of harvestable blocks and stand types, and curves that define the supply of elements with forest age. We used the harvest schedule and block map (rasterized) from the spatial timber supply to disturb a base landscape of biogeoclimatic (BEC) subzone variants. Subzone variants found on the Arrow TSA were grouped according to their similarity to the four most common subzones for which we had developed conceptual models (Table 1).

**Table 1.** Biogeoclimatic (BEC) subzone conceptual models applied to different subzone variants occurring on the Arrow Timber Supply Area (TSA).

| BEC subzone conceptual model | BEC subzone variants found on Arrow TSA |
|---|---|
| ESSFwc | ESSFwc1, ESSFwc4, ESSFwcp4, ESSFdc1 |
| ICHdw | ICHdw, ICHxw, IDFun |
| ICHmw | ICHmw2 |
| ICHwk | ICHwk1, ICHvk1 |

Simfor output included maps of Arcview-compatible (Environmental Systems Research Institute, Redlands, CA) grids depicting the supply of habitat elements at 10-year intervals. An Arcview script provided with Simfor was used to generate aspatial summaries of habitat elements over the planning horizon.

### Snags

Abundance of functional snags over time was modelled on the basis of empirical information for three parameters: stem density at time zero (*i.e.*, immediately following a stand-replacing disturbance), fall rate, and recruitment rate (Appendix I). We considered functional snags to be those >30 cm dbh; that is, snags that can be used by most snag-dependent species for nesting, roosting, foraging and communication.

Initial post-disturbance stem densities were set using the average number of stems/ha for live and dead trees from four sources: Arrow IFPA (Huggard 2000, Arrow IFPA 2002); the Provincial Ecology Program (Province of BC 2001); a natural disturbance study in the West Arm Demonstration Forest, Kootenay Lake Forest District (Quesnel and Pinnell 1998); and values derived from the Provincial Temporary Sample Plot Dataset (Steeger et al. 2000; Table 2). For natural and harvested stands, initial stem density equalled total stems/ha following fire or clearcutting with snag retention, respectively. Where sample sizes were low, we also interpolated snag abundance to adjust the values used in the forecast models.

Fall rates in the ESSFwc subzone were estimated from species-specific regression curves for snag longevity over 1-81 years following stand-replacing fires in Wenatchee and Okanogan National Forests, WA (Everett et al. 1999). Although the US study provided fall rates for Douglas-fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*), it was difficult to estimate overall fall rates for ICH subzones, due to the diversity of tree species found in ICH stands and their associated fall rates. Because Douglas-fir and lodgepole pine fall rates over the first 20 years following disturbance are similar to those of subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmanni*; Everett et al. 1999), we kept this rate the same for the different subzones; however, we assumed that decay and associated fall rates increased with moisture regime and the western hemlock (*Tsuga heterophylla*) component of the stand from ICHdw to ICHmw and ICHwk stands (Appendix I).

**Table 2.** Stems per hectare values for live and dead trees >30 cm in stands classified as either mature (101-250 years) or structural stage 6 (80-250 years), based on four datasets relevant to the Arrow Timber Supply Area. The values were used to set initial post-disturbance snag densities.

| | **Trees >30 cm dbh/ha** | | | |
|---|---|---|---|---|
| **Source** | **ESSFwc** | **ICHdw** | **ICHmw** | **ICHwk** |
| IFPA (Huggard 2000) | 161 | 129 | 164 | 308 |
| Provincial Ecology Program (Province of BC 2001) | 241 | | 497 | 375 |
| West Arm Demonstration Forest (Quesnel and Pinnell 1998) | 193 | 199 | 256 | |
| Provincial temporary sample plot data (Steeger et al. 2000) | | 189[1] | 222[1] | |
| Mean | 198 | 172 | 285 | 342 |

[1] Live trees only at stand age 100 years

Snag recruitment rates were estimated based on:

1. Time required for trees to grow to 30 cm dbh (IFPA data; Huggard 2000)
2. Differences in reported site index values for site series within the different ICH subzones (Province of BC 1997)
3. IFPA data on snag densities in structural stage 6, adjusted by live tree mortality rates reported by Huggard (2000)
4. Fall rates of recruited snags (Everett et al. 1999)

Models were also adjusted to reflect snag abundance data from plots measured on the Arrow TSA (Arrow IFPA 2002; Figure 2).

### Downed Wood

We based projection of downed wood on a volume-time since disturbance model stratified by disturbance type (natural and harvesting) and biogeoclimatic subzone. The model was based on (after Agee and Huff 1987):

1. Estimated volumes and retention times of downed wood on the ground at the time of disturbance. We built models from base volumes of downed wood that we defined as the expected mean volume on the ground in old-seral stands at the time of disturbance events. These volumes were lowest in dry subzones and highest in wet ICH and ESSF subzones (Stevens 1997). Retention times were also longer in wetter subzones because pieces are larger and larger pieces take longer to decay (Stevens 1997, Feller 1997), although western hemlock logs decay faster than Douglas fir logs of similar size (Mellen and Ager 2002). We assumed that utilization standards would result in volumes at the time of harvesting that would be 25% of those existing in stands at the time of a natural disturbance.
2. Estimated volumes and retention times of downed wood recruited during disturbance events. We estimated that downed wood volumes immediately following a natural disturbance increased by 50% due to tree death and injury (Harmon et al. 1996). We considered downed wood lost to fire to be small diameter pieces that would contribute little to volume estimates. Downed wood volumes recruited by disturbance were assigned longer retention times than existing volumes because pieces added by disturbance would all be in early decay classes, in contrast with the distribution of decay classes found among downed wood pieces already on

the ground at the time of disturbance. We assumed that downed wood recruited by harvesting added 25% to the pre-disturbance volume. Harvesting and utilization standards results in smaller pieces and, hence, smaller volumes of wood left in harvested stands compared to naturally disturbed stands, post-disturbance. Downed wood volumes added by harvesting were assigned shorter retention times compared to volumes already on the ground because of their smaller diameter classes (Stevens 1997, Huggard 2000) and because the warmer microclimate that occurs after the removal of forest canopy stimulates decay (Rose et al. 2001).

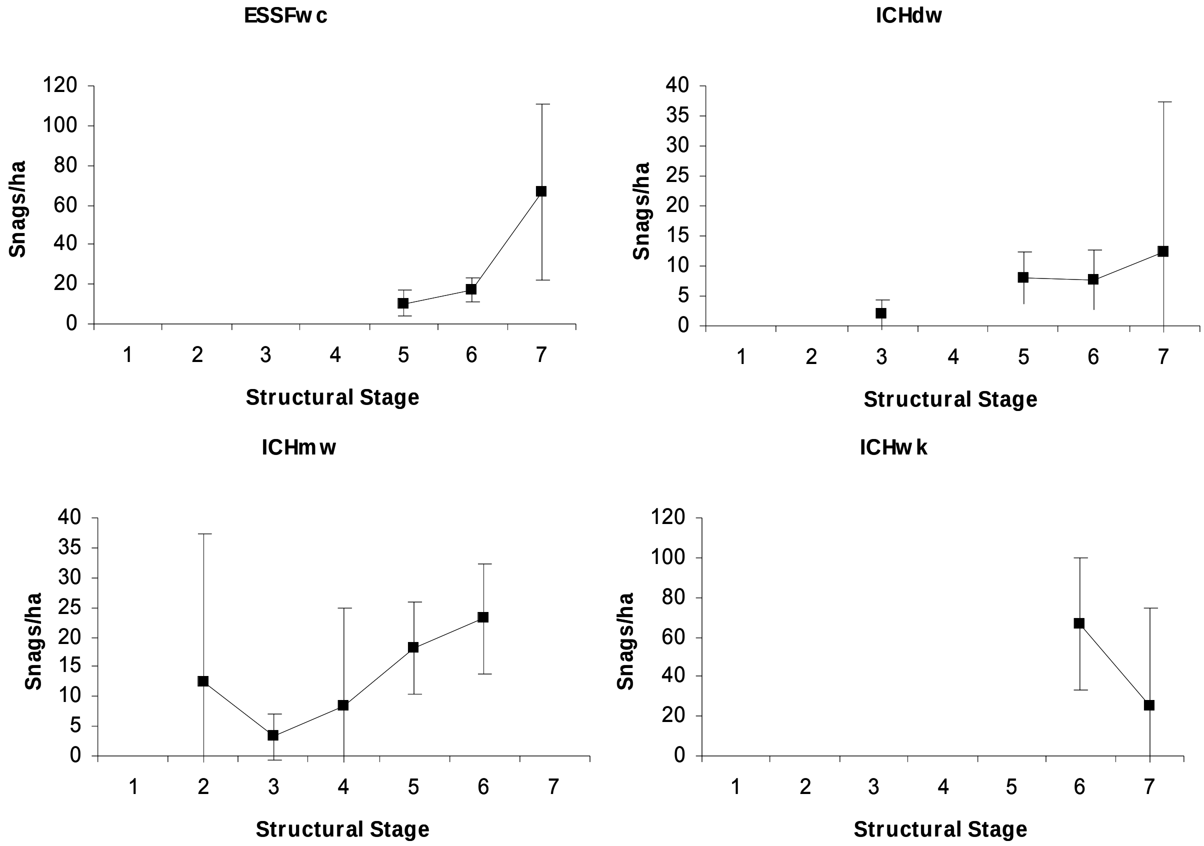

**Figure 2.** Stems per hectare values for snags >30 cm by BEC subzone and structural stage in Arrow TSA stands, based on plot data collected during IFPA projects (IFPA 2002).

3. <u>Recruitment and retention of downed wood volume in the maturing forest</u>. We assumed that trees achieved sufficient age and size to die, fall down and contribute significantly to downed wood volumes beginning at age 100 in ESSF and age 50 in ICH stands. We modelled net recruitment of downed wood, which is the sum of volume recruited minus volume decaying. We further assumed that downed wood volumes would achieve a steady state (recruitment equalling decay) in late-seral stands at age 500 in the ESSF and at age 250-350 in the ICH (later ages for wetter subzones; Steven 1997).

Parameters applied to the conceptual models were derived from downed wood data collected on the Arrow TSA (Arrow IFPA 2002; Figure 3) and on Huggard (2000; Appendix I).

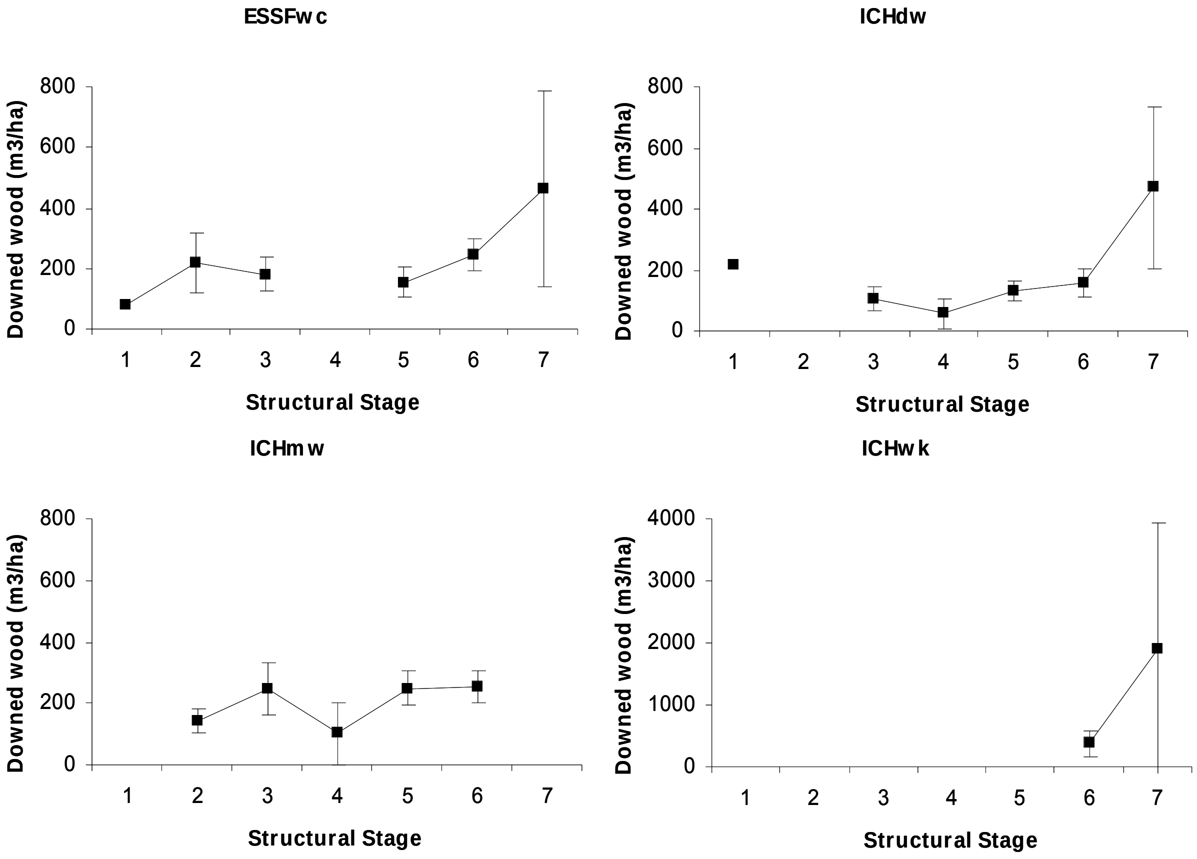

**Figure 3.** Volumes of downed wood recorded on sample plots in the Arrow Timber Supply Area (Arrow IFPA 2002). Mean volume of ICHwk plots was inflated by two very large diameter pieces.

### Hardwoods

There was little published information to guide a conceptual model to define the dynamics of hardwood abundance in natural and harvested stands; however, there were several general principles on which we based our estimates of hardwood abundance (S. Simard, *pers. comm.*):

- Significance hardwood abundance occurs only in drier subzones (ICHdw and ICHmw)
- Drier sites within subzones are associated with more abundant hardwood cover
- Hardwood abundance peaks 20-40 years following disturbance
- Hardwoods are seral species that are generally absent from stands by 140 years after disturbance
- Hardwood abundance is severely depressed by stand-replacing fires
- Hardwoods retained after harvesting do not live long
- Hardwoods are aggressively suppressed in young stands through brushing
- Small diameter hardwoods are captured in shrub cover models
- Pre-disturbance and adjacent hardwood abundance is an important determinant of post-disturbance abundance; however, this was not possible to model in our projections

We examined the forest cover database to determine the percent composition of hardwoods in stands of different ages typical of different subzones (Figure 4). We used these data to establish parameters for our model curves (Appendix I). We assumed that no significant hardwood composition occurred (above the shrub layer) in natural stands in the ICHwk or ESSFwc, or in any harvested stands.

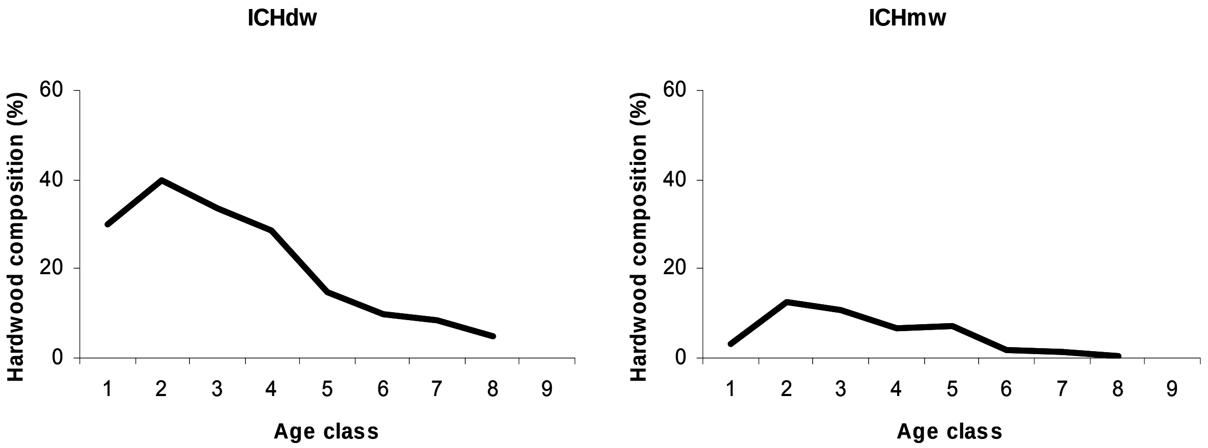

**Figure 4.** Average percent composition of hardwood trees species by age class in stands typical of ICHdw and ICHmw subzones on the Arrow Timber Supply Area, according to the forest cover database.

### Shrub Cover

We assumed that shrub cover throughout the Arrow TSA peaks in relatively early seral stages, declines during stem exclusion because of shading and competition, and then increases as the stand ages and the canopy begins to differentiate into >1 canopy layer. We also assumed that shrub cover is suppressed through brushing in all, recently harvested stands. Parameters associated with this conceptual model were derived from data collected on the Arrow TSA (Arrow IFPA 2002; Appendix I). Data were too sparse to provide all parameters (Figure 5).

### Seral Stage

Seral stage distribution was reported according to BEC subzone-specific class limits, adapted from BEC structural stages (Province of BC 1998; Table 3).

**Table 3.** Seral stage definitions used in projection models, by biogeoclimatic (BEC) subzone.

| | **Seral stage definitions (years)** | | | |
|---|---|---|---|---|
| **BEC subzone** | **Early** | **Mid** | **Mature** | **Old** |
| ESSF | ≤40 | 41-80 | 81-250 | >250 |
| ICH | ≤20 | 21-80 | 81-140 | >140 |
| IDF | ≤20 | 21-80 | 81-140 | >140 |

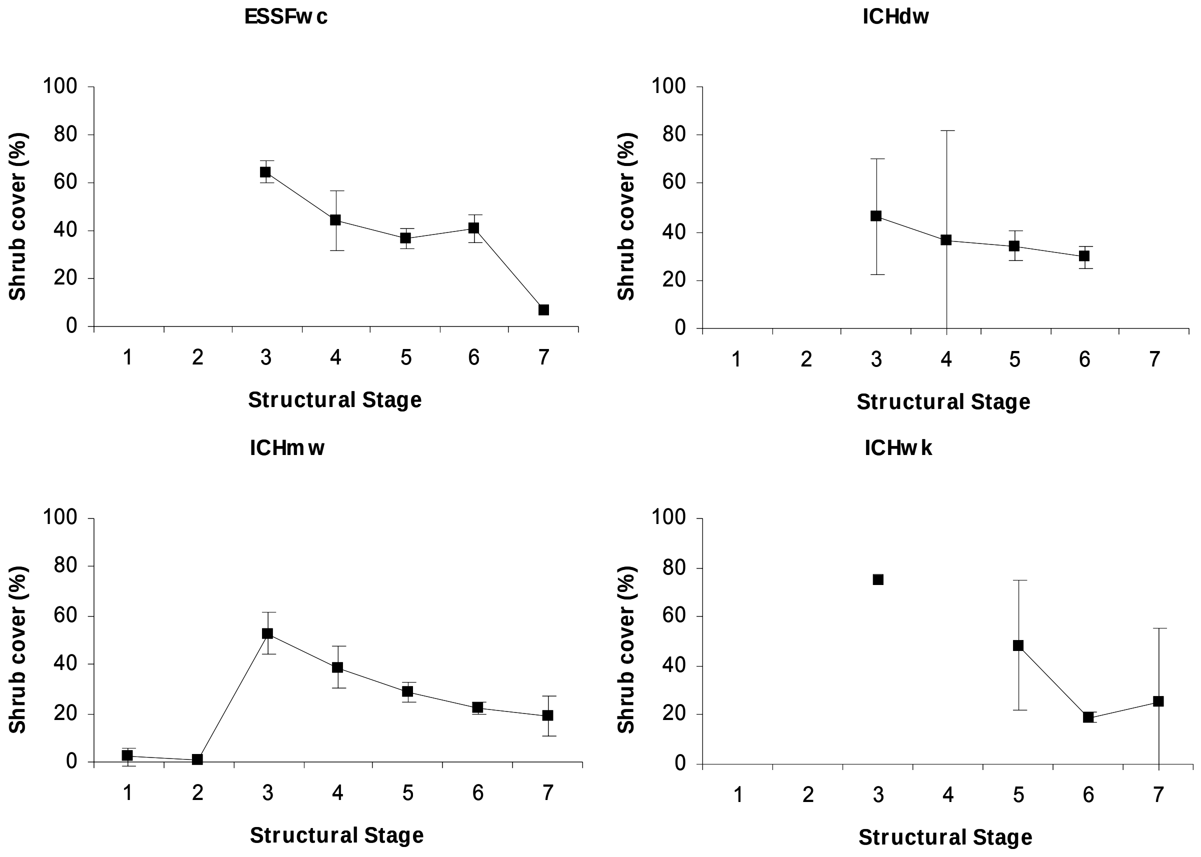

**Figure 5.** Shrub cover by biogeoclimatic subzone among plots investigated during projects conducted on the Arrow TSA (Arrow IFPA 2000).

### *Habitat Suitability Index Models*

#### Pileated Woodpecker

We developed a habitat suitability index model for the nesting/roosting and feeding habitat of pileated woodpeckers (*Dryocopus pileatus*). The model was based on the following habitat attributes:

1. Snags. Pileated woodpeckers nest and feed in large-sizes snags. Forage trees are required in much higher numbers than nest and roost trees; therefore, we based ratings for habitat suitability on the abundance of forage trees. Ecologically functional snags for pileated woodpeckers are >30 cm dbh (Bull and Jackson 1995, Steeger and Dulisse 2001). Viable pileated woodpecker populations have been found in stands containing 10 functional snags/ha (Bull and Holtausen 1993). Guidelines for pileated woodpecker management areas in Oregon and Washington call for 120 ha areas of old-growth forest plus 120 ha habitat patches with >5 snags/ha. Based on these results we developed a habitat suitability index curve that described the relationship between suitable habitat for pileated woodpeckers and different densities of functional snags (Figure 6).
2. Downed wood. Pileated woodpeckers forage mostly on ants found in dead wood. Foraging substrates used by pileated woodpeckers have been estimated to be: downed wood 38%, snags 38%, live trees 18% and stumps 6%. Preferred downed wood pieces are ≥38 cm diameter with extensive decay (Bull and Jackson 1995). Pieces <17 cm in diameter are rarely used Bull and Meslow 1977). We assumed that maximum usable levels of downed wood would be reached relatively quickly because other substrates make up the majority of foraging sites. We further assumed that at low levels of downed wood (<50 $m^3$/ha), no pieces would be large enough to contribute to foraging habitat. Based on these results we developed a habitat suitability index

curve for pileated woodpeckers that described the relationship between suitable habitat and different volumes for downed wood (Figure 6).

3. Hardwoods. In the Arrow TSA, mature aspen of wildlife trees class 2 (live defective) are the most common nest trees (Steeger and Dulisse 2001). Birch is not used for nesting; however, our projections did not separate different species of hardwoods. Mature aspen are available primarily in structural stages 5 and 6 on the THLB (*i.e.*, non-riparian stands). We assumed that the presence of any mature aspen within coniferous stands had high value for nesting (Figure 6).
4. Shrub cover. Pileated woodpeckers also eat fruits and berries (Bull and Jackson 1995), although observations of this behaviour are limited on the Arrow TSA. Such foods are seasonally very limited. We assumed that the maximum suitability of shrub cover would occur at relatively low cover values and would then decline because high shrub cover would tend to displace other more valuable habitat elements (Figure 6).

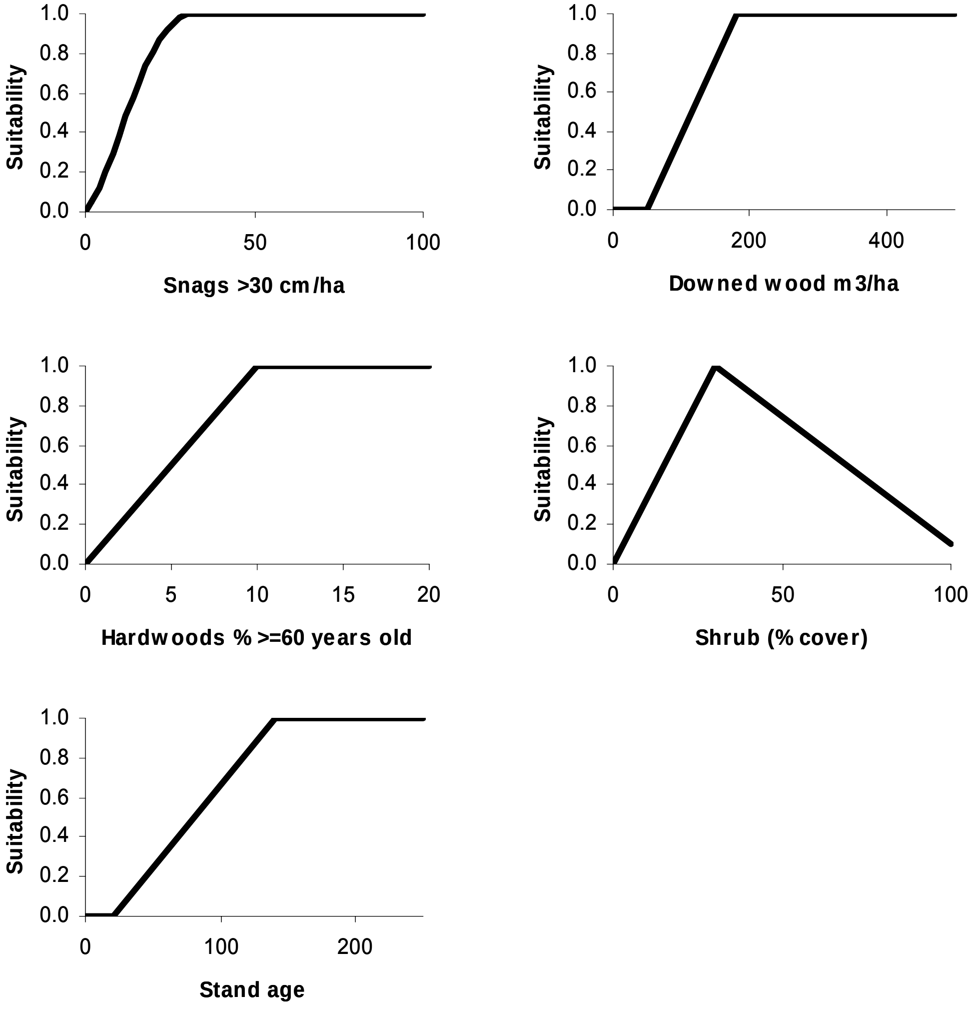

**Figure 6.** Habitat suitability index curves defining the pileated woodpecker nesting/roosting and feeding habitat model.

5. Seral stage. Pileated woodpeckers forage in young forests but prefer old-seral stands because they forage extensively on large live trees (Bull and Jackson 1995). Although a number of habitat elements captured by other curves are found in old-seral stands, a separate curve was developed to capture this use of large live trees (Figure 6).

Suitability curves for these habitat elements were combined to calculate habitat suitability for pileated woodpeckers according to the following equation:

$$HSI = 0.35*(Snags) + 0.25*(Seral\ stage) + 0.25*(Downed\ wood) + 0.1*(Hardwoods) + 0.05*(Shrub\ cover)$$

Mountain Caribou

We developed a habitat suitability index model for mountain caribou (*Rangifer tarandus*) based on BEC subzones and seral class. We considered the early winter season only because caribou are most likely to be located in operable forest during this period (25 October-15 January; Hamilton et al. 2000). We considered mature and late-seral stands capable of supporting caribou (Hamilton et al. 2000). Subzones (except AT and IDF zones) were rated according to the distribution of early winter locations recorded during inventory studies of the Central Selkirk caribou herd (Table 4; Hamilton et al. 2000, Hamilton and Wilson 2002).

As part of the model we had to estimate the capability of subzones outside the range of the Central Selkirk caribou herd. As a result, ratings for some subzones did not follow the distribution of telemetry points recorded during the inventory studies. For example, the ESSFwc subzone was used heavily in the Central Selkirk Mountains; however, this subzone is widely distributed both within the range of the Central Selkirk herd and throughout the Arrow region, where the historical range of caribou is unknown.

**Table 4.** Habitat suitability index ratings for the early winter season (25 October-15 January) for mountain caribou on the Arrow Timber Supply Area, by biogeoclimatic (BEC) subzone (zones for AT and IDF). The number of telemetry locations (early winter only) and selection ratios (proportion used/proportion available within the Arrow portion of the Central Selkirk mountain caribou inventory study area) recorded during telemetry studies of the Central Selkirk mountain caribou herd (Hamilton et al. 2001, Hamilton and Wilson 2002) are also listed.

| BEC subzone | Habitat suitability index | Caribou locations | Selection ratio |
|---|---|---|---|
| AT | 0 | 5 | - |
| ESSFvc | 0.2 | 0 | 0 |
| ESSFwc | 0.7 | 221 | 0.9 |
| ESSFdc | 0.1 | - | - |
| ICHdw | 0.2 | 0 | 0 |
| ICHmk | 0 | - | - |
| ICHmw | 0.8 | 84 | 1.0 |
| ICHvk | 0.4 | 3 | 0.8 |
| ICHwk | 1.0 | 79 | 1.7 |
| ICHxw | 0 | - | - |
| IDF | 0 | - | - |

# Results

*Attribute Supply on the Arrow TSA*

Snags

Snag projections predicted that high densities (>100/ha) of functional snags will disappear from the THLB within 30 years and that the land base will become increasingly dominated by stands with <5 functional snags/ha (Figure 7). Most of this conversion is predicted to occur within the next 70 years, after which the aspatial distribution of snag density classes will remain relatively constant.

Downed Wood

Supply projections predicted that high volumes of downed wood (>300 $m^3$/ha) will disappear from the THLB in about 60 years (Figure 8). Stands with <100 $m^3$/ha are predicted to increase from <50% of the THLB to >80% within approximately 100 years.

Hardwoods

Stands with high proportions of hardwoods (>30% stand composition) are currently rare on the THLB and are expected to decline slowly and disappear over the next 70 years (Figure 9). Stands with lower proportions of hardwoods are expected to persist for longer, but all hardwoods (in the canopy layer) are expected to disappear within approximately 160 years.

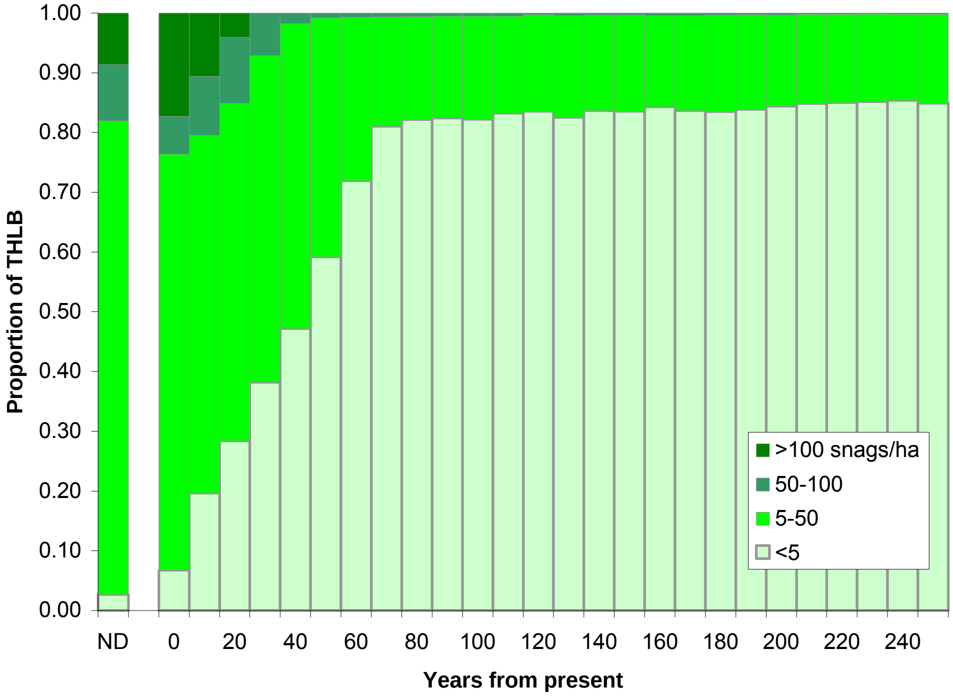

**Figure 7.** Snag densities (>30 cm dbh) on the timber harvesting land base of the Arrow Timber Supply Area. Densities are projected from 10-250 years from present. Harvest scheduling was based on the Arrow IFPA's spatial timber supply analysis (Timberline 2002). "ND" refers to a natural disturbance regime, based on the Biodiversity Guidebook.

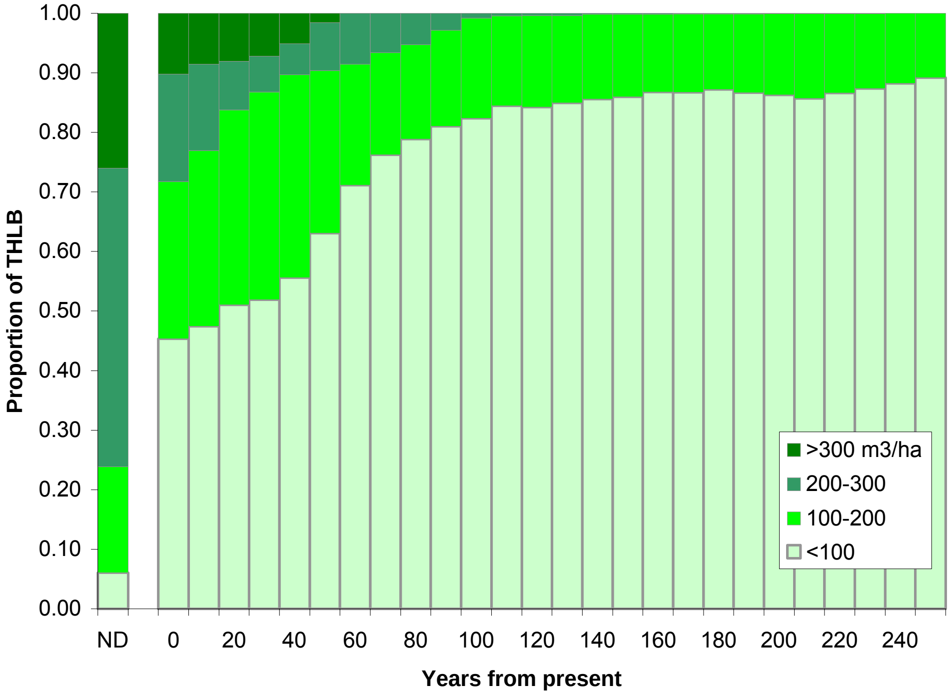

**Figure 8.** Downed wood volumes on the timber harvesting land base of the Arrow Timber Supply Area. Volumes are projected from 10-250 years from present. Harvest scheduling was based on the Arrow IFPA's spatial timber supply analysis (Timberline 2002). "ND" refers to a natural disturbance regime, based on the Biodiversity Guidebook.

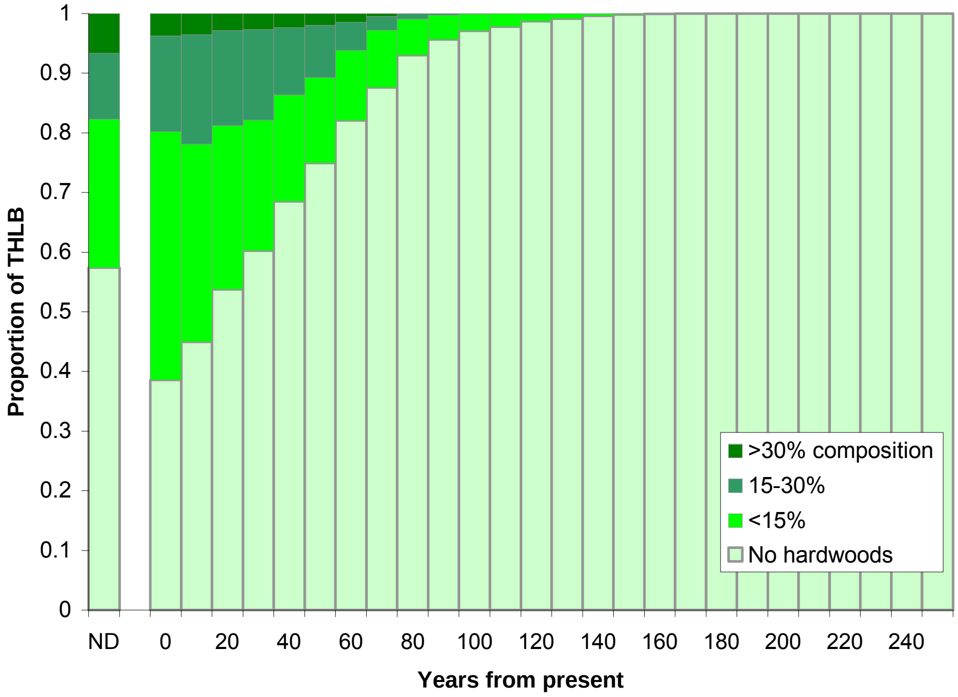

**Figure 9.** Percent composition of hardwoods on the timber harvesting land base of the Arrow Timber Supply Area. Composition is projected from 10-250 years from present. Harvest scheduling was based on the Arrow IFPA's spatial timber supply analysis (Timberline 2002). "ND" refers to a natural disturbance regime, based on the Biodiversity Guidebook.

Shrub Cover

Stands with >50% shrub cover are rare in the THLB and are projected to disappear within 40 years (Figure 10). Supply projections suggested that stands dominated by low shrub cover (<20%) will increase from <20% to >60% of the THLB within 80 years.

Seral Stage

According to our supply projections, the biggest change to seral stage distribution on the THLB will be an increase in the proportion of stands dominated by mid-seral forests from approximately 15% to 50% over 250 years (Figure 11). This will be associated with a decline in the area covered by mature and late-seral forests. The biggest changes in seral stage distribution are expected in the next 100 years.

If the area of productive forest in the Arrow TSA is considered in projections rather than just the THLB, the seral stage predictions change dramatically (Figure 12). Specifically, late-seral forests come to dominate approximately 50% of the productive forest, mostly due to aging of currently mature stands. The area dominated by early and mid-seral stands increase by approximately 10% over the 250-year projection, with most of the increase coming in the first 70 years.

*Habitat Supply on the Arrow TSA*

Pileated Woodpecker

Habitat supply projections for pileated woodpecker predicted a large decline in *high* and *moderate* suitability habitat in the THLB (Figure 13). The net result was a predicted increase in *low* suitability habitat from <20% to >90% of the THLB. Most of the change in habitat suitability is expected in the next 100 years.

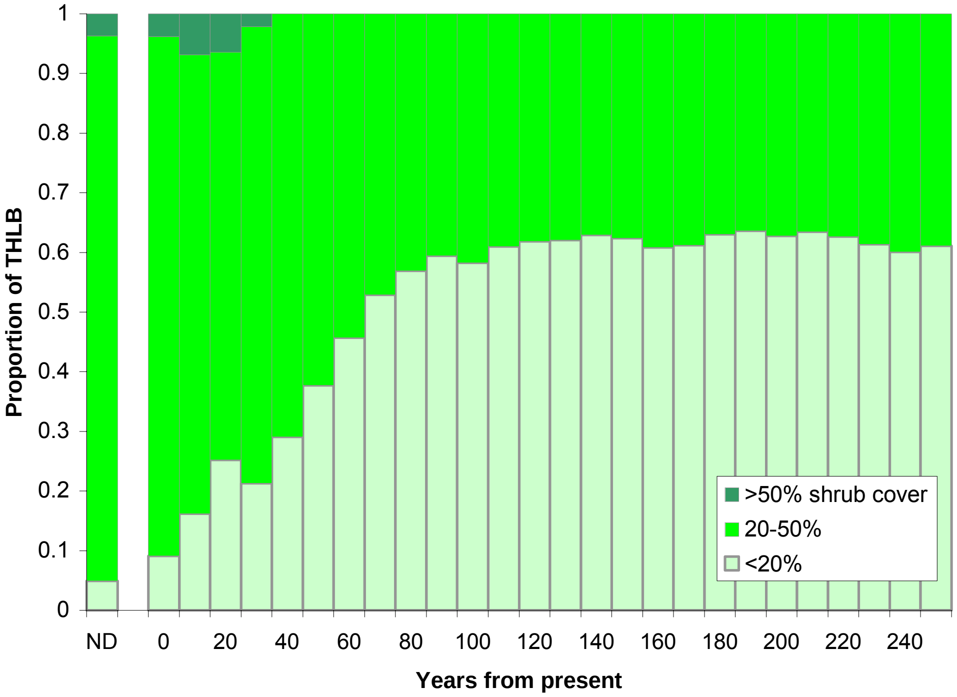

**Figure 10.** Percent shrub cover on the timber harvesting land base of the Arrow Timber Supply Area. Shrub cover is projected from 10-250 years from present. Harvest scheduling was based on the Arrow IFPA's spatial timber supply analysis (Timberline 2002). "ND" refers to a natural disturbance regime, based on the Biodiversity Guidebook.

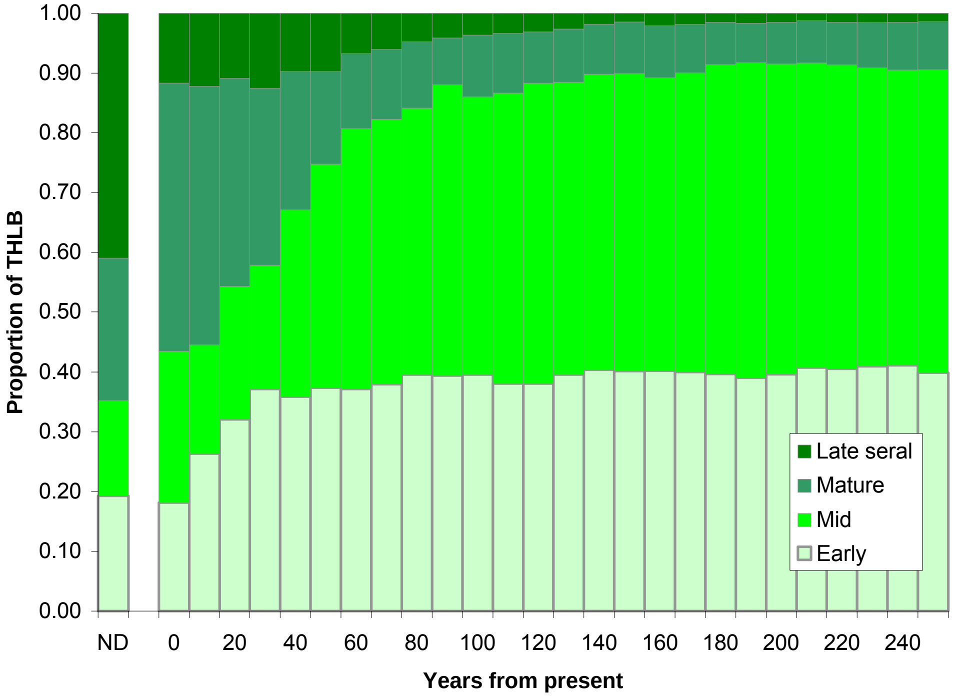

**Figure 11.** Seral stage distribution of the timber harvesting land base of the Arrow TSA. Seral distribution is projected from 10-250 years from present. Harvest scheduling was based on the Arrow IFPA's spatial timber supply analysis (Timberline 2002). "ND" refers to a natural disturbance regime, based on the Biodiversity Guidebook.

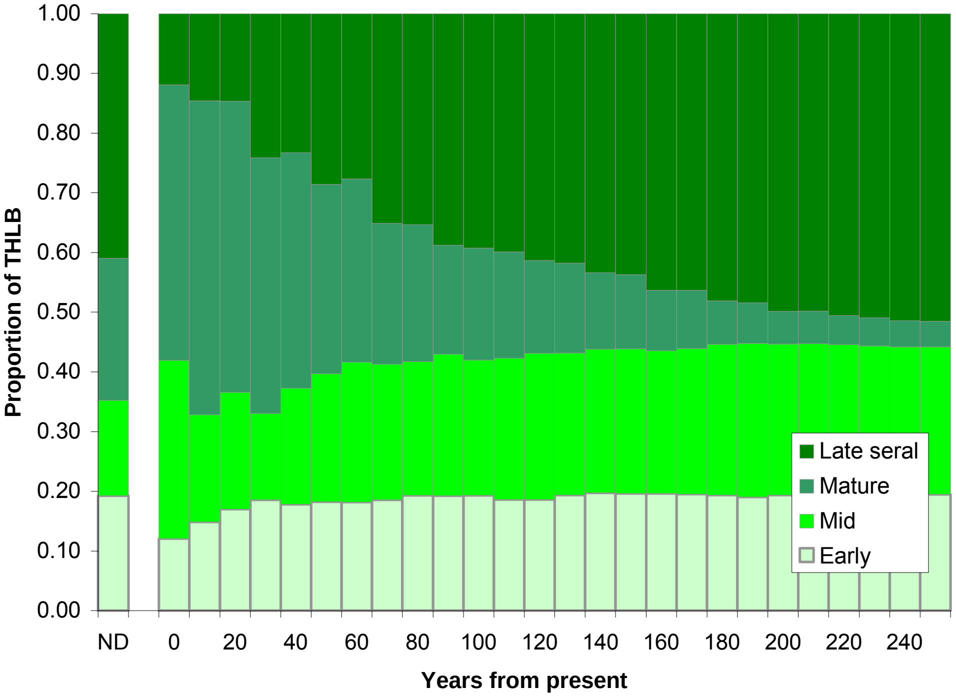

**Figure 12.** Seral distribution of stands within the area of productive forest on the Arrow Timber Supply Area. Seral distribution is projected from 10-250 years from present. Harvest scheduling was based on the Arrow IFPA's spatial timber supply analysis (Timberline 2002). "ND" refers to a natural disturbance regime, based on the Biodiversity Guidebook.

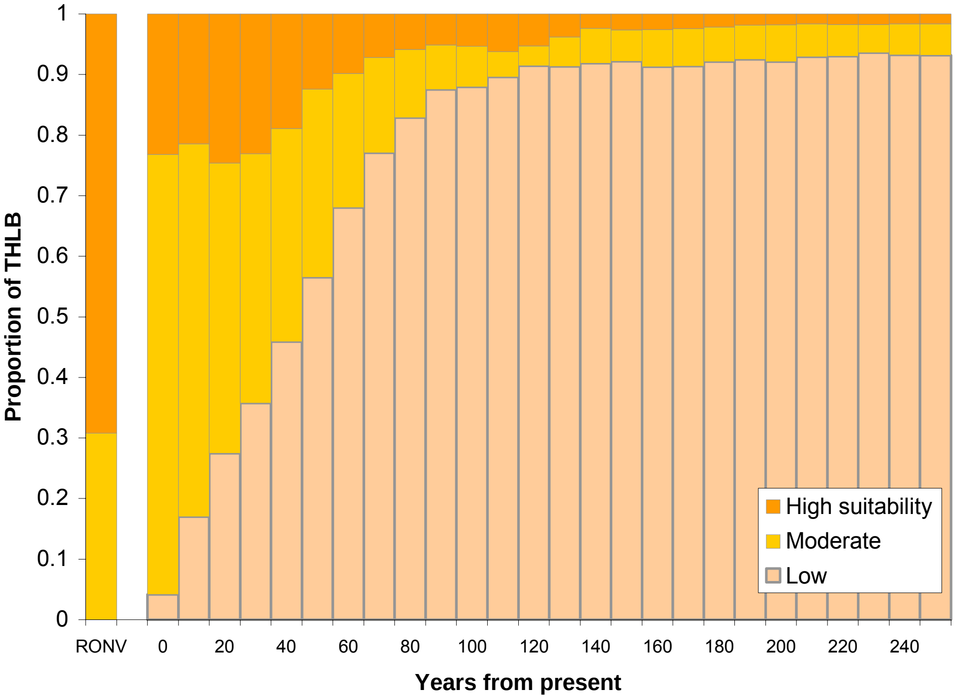

**Figure 13.** Pileated woodpecker habitat suitability on the timber harvesting land base of the Arrow Timber Supply Area. Habitat suitability is projected from 10-250 years from present. Harvest scheduling was based on the Arrow IFPA's spatial timber supply analysis (Timberline 2002). "ND" refers to a natural disturbance regime, based on the Biodiversity Guidebook.

Mountain Caribou

Approximately half of the THLB is currently high quality early winter habitat for mountain caribou and this proportion is expected to decline to approximately 10% over the next 250 years (Figure 14). The habitat suitability model classified very little of the THLB as *moderate* habitat.

# Discussion

## Habitat Supply on the Arrow TSA

This project is the first attempt to model the implications of the harvest schedule associated with the Arrow TSA's spatial timber supply analysis (Timberline 2002) on the long-term abundance of important habitat elements. The method we developed was based on the use of existing tools and had clear links to the Arrow IFPA's criteria and indicators for sustainable forest management.

### *Snags*

Dead standing trees provide habitat for invertebrates, lichens and fungi, and approximately 25-30% of vertebrate fauna occurring in ICH, IDF and ESSF forests rely on tree cavities for reproduction or roosting (Bunnell et al. 1999). Primary cavity excavators require some element of decay in trees to generate functional cavities (Rose et al. 2001).

Our supply projections suggested that high densities of snags will disappear on the Arrow THLB within 30 years, and that the dominant landscape change with respect to snags will be a conversion to stands with very low snag densities. This conversion will occur in the next 70 years as old growth is replaced with second-growth stands that are harvested before significant functional snag densities develop.

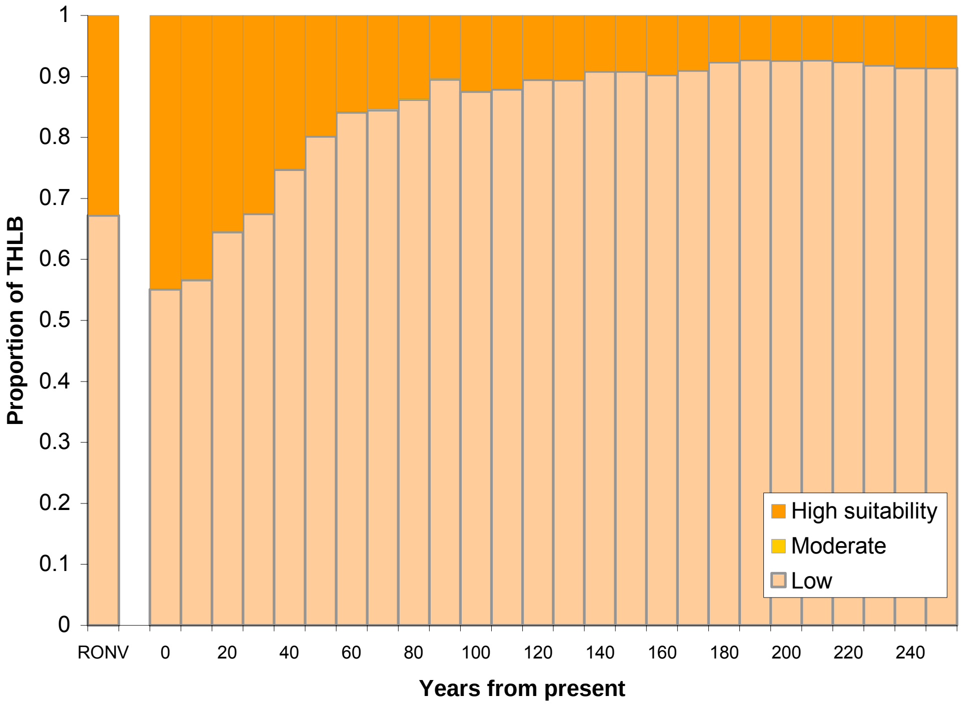

**Figure 14.** Mountain caribou habitat suitability for the early winter season on the timber harvesting land base of the Arrow Timber Supply Area. Habitat suitability is projected from 10-250 years from present for the early winter season (25 October-15 January; Hamilton et al. 2000). Harvest scheduling was based on the Arrow IFPA's spatial timber supply analysis (Timberline 2002). "ND" refers to a natural disturbance regime, based on the Biodiversity Guidebook.

We reported aspatial densities of snags over the planning horizon; however, the arrangement of snags in space is as important as their abundance over time. We need to develop methods to measure the patchiness of snags in natural forests and to develop guidelines for managed stands that reflect ecologically appropriate distributions.

Although the importance of snags is well understood, there are few consistent estimates of threshold tree sizes or densities to guide management. Larger trees (>30 cm dbh) are required by some species (*e.g.*, woodpeckers, some owls, raptors, marten), and smaller species (*e.g.*, chickadees, nuthatches, squirrels) appear to prefer larger trees (*e.g.*, nuthatches; Steeger and Hitchcock 1998). Larger trees are also preferred as foraging sites, especially by woodpeckers foraging for insects in wildfire burns (Hutto 1995). Woodpecker foraging on unburned trees was found to be concentrated in the 20-50 cm dbh class (Quesnel et al. 1997). Recommended snag densities vary between 5-10 functional wildlife trees/ha (Bull and Holtausen 1993, Steeger and Machmer 2002).

### *Downed Wood*

Downed wood is an ecologically important component of forests, providing habitat for vertebrates and invertebrates and influencing basic ecosystem processes such as soil development and productivity, nutrient immobilization and mineralization, as well as nitrogen fixation (Rose et al. 2001). Downed wood also serves as a nutrient source and substrate for tree seedlings and fungi (Harmon et al. 1996). Species richness of terrestrial vertebrates increases with increasing volumes of downed wood (Maguire 2002).

The usefulness of downed wood to animals is heavily influenced by piece size. In general, some requirements of the smallest mammals such as shrews and mice can be satisfied by pieces as small as 6 cm in diameter (Craig 1995); however, larger species such as black bears (*Ursus americanus*) require logs >140 cm in diameter (Davis 1996).

Decay influences the importance and function of downed wood to wildlife. Recently downed wood can be used for cover by deer mice and terrestrial shrews, and perching sites for squirrels and birds (Maser et al. 1979). Downed wood is also an important structural element in streams and larger waterbodies for species such as water shrews (*Sorex palustris*; Craig and Wilson 2001). More decayed downed wood is colonized by insects and provides foraging sites for shrews, mice, birds and black bears (Maser et al. 1979). Spaces under loose bark provide important thermal and security cover for amphibians and small mammals (Maser et al. 1979). Small mammals burrow into heavily decayed logs to create nest sites, which are subsequently used by amphibians, weasels, and squirrels (Maser et al. 1979).

Like snags, downed wood is patchily distributed in forests and volumes differ significantly among different forested ecosystems and disturbance histories (Stevens 1997; Ohmann and Waddell 2002). Interpreting estimates of downed wood in the context of the Arrow IFPA is difficult because sample sizes are often inadequate to capture the significant variability among sites (*e.g.*, Stevens 1997). In addition, researchers use different measures to quantify downed wood (*e.g.*, mass versus volume; Feller 1997).

Much like our projections for wildlife trees, stands dominated by high volumes of downed wood is predicted to disappear as the THLB is converted to second growth. Utilization standards in harvested stands and the nature of wood left on sites after harvesting (*i.e.*, smaller pieces than created by natural disturbances) is responsible for this landscape change. Despite a significant body of work, obvious threshold volumes of downed wood have not emerged (Bunnell et al. 1999). As a result, few studies have related down wood volumes to species requirements (Carey and Johnson 1995), although Craig (2002) found that red-backed voles (*Clethrionmys gapperi*) and long-tailed voles (*Microtus longicautus*) responded strongly to the removal of downed wood from harvested sites and recommended that at least 80 $m^3$/ha and 300 $m^3$/ha be maintained in IDF and ESSF forests, respectively.

### *Hardwoods*

Deciduous broad-leaved hardwood trees serve many functions in forests. Their leaves provide insects for foraging birds, and their leaf litter hosts a diverse community of invertebrates. Hardwoods also provide a substrate for epiphytic bryophytes and lichens (Bunnell et al. 1999). Hardwoods decay faster than conifers and therefore become available for cavity excavation at younger ages (Bunnell et al. 1999).

Hardwoods in managed stands are generally less abundant than in natural stands of the same age because they are suppressed to enhance conifer growth. Because they are seral species that naturally decline in abundance as stands age, they are also becoming rare in natural stands as a result of fire suppression (S. Simard, *pers. comm.*). In general, hardwoods are more common in drier ecosystems and are generally absent in subzone variants found in wetter areas or at higher elevations (Braumandl and Curran 1992).

Hardwoods in our projections were eliminated from the THLB by about 160 years because we assumed that hardwoods in the canopy layer would be absent from managed stands. Active suppression in the Kamloops Forest District has resulted in pure conifer stands in some areas (S. Simard, *pers. comm.*). We expected hardwoods to continue to persist in the understorey and sub-canopy layers, where they would be captured by our shrub cover models.

### *Shrub cover*

Many bird species use shrubs for nesting habitat, nesting cover, or as a foraging substrate (Bunnell et al. 1999). In addition, browsing ungulates such as moose and deer species make extensive use of shrub cover (Bunnell et al. 1999).

Quantifying shrub cover on the Arrow IFPA was relatively easy because a plot cover estimate is part of the data recorded on the Ground Inspection Form (RIC 1998). Unfortunately, we found that several IFPA projects did not record this parameter.

Our projections suggested an increase in stands dominated by low shrub cover and the elimination of stands with >50% shrub cover. This might seem counter-intuitive because shrubs respond strongly to forest harvesting (Dyrness 1973); however, shading and competition with young trees in mid-seral forests results in low shrub cover, and forests were harvested again in projections before high shrub cover re-established. In addition, we assumed that shrub cover in harvested stands was suppressed by brushing.

### *Seral Stage*

Rather than a specific habitat element, seral stage distribution is a broad indicator of habitat suitability for a large number of vertebrate species. About 33% of vertebrates found in British Columbia are associated with habitat elements that are abundant in late-seral forests (Bunnell et al. 1999). These habitat elements include downed wood and snags which we captured in separate models; however, there are other characteristics associated with older forests, such as low levels of habitat fragmentation, that are likely important for species such as mountain caribou (MCTAC 2002).

Our projections suggested a large increase in early and mid-seral forests as stands in the THLB are converted to second growth over the next 80 years. The mature and late seral components persisted throughout the projections because of harvesting constraints modelled in the timber supply analysis (*e.g.*, visual quality objectives; Timberline 2002). Seral stage distribution was very sensitive to the inclusion of inoperable forest in projections. This sensitivity increased in later years of the projections due to continuous aging in the operable.

## Monitoring Habitat Supply with Indicator Species

### *Pileated Woodpecker*

The pileated woodpecker was a good species for modelling habitat supply on the Arrow TSA because it is associated with all the habitat elements we modelled for various aspects of its life history. It uses snags, downed wood and shrubs for foraging, as well and wildlife trees and hardwoods for nesting. We used the supply of late seral stands to indicate the abundance of large, live trees, on which pileated woodpeckers forage extensively (Bull and Jackson 1995). Projections of pileated woodpecker habitat reflected the close association of this species with snags and late-seral stands.

### *Mountain Caribou*

In the Arrow TSA, mountain caribou typically use ICH and ICH-ESSF transition forests during the early winter season (Hamilton et al. 2000). High quality habitat for mountain caribou in the early winter season declined over time in our projections; however, much of the high quality habitat identified by our model is currently unoccupied because caribou populations are very small and restricted to the northern third and extreme southeast portions of the Arrow TSA (Hamilton et al. 2000, Hamilton and Wilson 2002, MCTAC 2002).

Mountain caribou are a relatively poor indicator species for habitat supply modelling because they are currently very rare, even in suitable habitat. This makes verification of models difficult and limits the usefulness of habitat projections.

## Key Assumptions and Limitations

Our habitat supply analysis was based on a number of key assumptions and limitations, including:

- <u>The analysis considered only the THLB</u>. As a result, the inoperable, productive forest component of the Arrow TSA aged continuously throughout the 250-year projection, biasing the seral stage distribution towards old forest (Figure 12). To avoid this bias, we reported our results mostly for the THLB only. Licensees are looking to inoperable forest to provide important habitat elements that are lost as a result of harvesting on the THLB, but reporting habitat supply within the productive forest instead of the THLB would have produced misleading results, based on the available harvest schedule. A harvest schedule that addresses additional disturbance types both inside and outside the THLB would largely address this problem but projections will always be sensitive to the proportion of inoperable productive forest included in the analysis.

- Habitat types other than productive forest were not considered. Riparian habitat is an important indicator of biological richness; however it was not considered in the analysis because it is netted out of the THLB. Others habitats such as avalanche chutes and subalpine parkland also make important contributions to biological richness at a landscape scale. These habitats should be mapped and seral dynamics modelled in a way that they can also be included in habitat supply analyses.
- Clearcutting was the only disturbance treatment. As a result, our habitat supply projections were also limited to this single disturbance type. Clearly, other natural disturbances (fire, disease, etc.) and harvest treatments (partial cutting, commercial thinning, etc.) are expected on the landscape over the next 250 years. When timber supply projections that accommodate these disturbances become available, the habitat supply models developed for this project (and additional models for silviculture treatments), can be used to estimate the implications of these additional disturbances for habitat supply.
- Time zero was considered current conditions. There was no explicit examination of habitat elements already lost due to current forest practices.
- Supply models were based on sparse data and were stratified by BEC subzone. Grouping of ecosystems to the subzone scale for modelling habitat supply was a gross simplification of the landscape. Separate models were not developed for rare BEC subzones because no data were available with which to set parameters. In addition, although data did exist to set some parameters for some models, much data were unusable because they were collected by different methods and to different standards.
- Timber and habitat supply analyses were based on different base maps. The spatial timber supply analysis used a polygon-based map of timber units (Timberline 2002) while the habitat supply analysis was based on a raster map of BEC subzone variants. This limited the spatial resolution of the habitat supply analysis to 1-ha, despite a large number of very small harvesting events in the harvest schedule.
- Coarse benchmarks were used to gauge habitat changes. Our projections indicated expected changes in the supply of habitat attributes; however, the only benchmarks available to provide context were coarse estimates based on the Biodiversity Guidebook (BC Ministry of Environment 1995).

## Recommendations

1. Develop guidelines concerning the spatial extent of habitat supply analyses. Results of any analysis are going to be influenced strongly by the inclusion of areas that are not harvested. In effect, nearly any supply shortfall can be hidden aspatially in inoperable forest. This is partly an issue of continuous aging of the inoperable forest in supply projections; however, as long as natural disturbances are modelled on intervals that are longer than the harvest rotation, habitat elements associated with late-seral forests will always be more available in the inoperable.
2. Explore the spatial implications of habitat supply. Although the output of habitat supply projections are usually maps, we focus on aspatial summaries to indicate trends in habitat supply. There are important questions that need to be answered that are related to the spatial arrangement of habitat:
    a. What is the optimal distribution of habitat elements and/or habitat for indicator species on the THLB, the productive forest and the entire planning unit (*e.g.*, TSA or TFL)?

    b. What is the optimal distribution of habitat elements at smaller spatial scales than the habitat supply projections can resolve? For example, how should retained downed wood or snags be distributed at the stand scale?

    c. What metrics can be used to measure the spatial distribution of habitat elements?

3. <u>Extend mapping to areas outside the area of productive forest</u>. Understanding the dynamics of habitat supply requires a consideration of the entire landscape; however, mapping is usually limited outside the THLB. In addition, some important habitats are not found in productive forest by definition (*e.g.*, riparian corridors, avalanche chutes, rock bluffs). These habitats need to be considered in analyses.

4. <u>Reconcile forest cover mapping with ecological mapping</u>. Working from a single base map streamlines habitat supply modelling.

5. <u>Measure stand structure associated with common silviculture treatments and develop methods to track habitat elements in treated stands</u>. Little is known about residual stand structure in partially cut or otherwise treated stands. Models to track such structure are currently rudimentary (Wilson et al. 2002).

6. <u>Existing standards should be leveraged to generate usable databases of structure information</u>. Most of the stand level information required to develop and test habitat supply models can be collected in standardized plots (RIC 1998). Ground Inspection Forms should be used for all plot work, in addition to project-specific data.

7. <u>Continue to refine conceptual models based on existing information</u>. Sophisticated models that integrate broad knowledge about the dynamics of habitat elements at the stand scale are now available and could be interpreted and extended to refine landscape-level conceptual models. We used broad parameters from Huggard (2000), but other models are also available (*e.g.*, Greenough et al. 1999, Mellen et al. 2002).

8. <u>Further work is required to establish benchmarks and thresholds</u>. Habitat shortfalls can be identified only where thresholds are available to indicate a deficiency. Developing indicators associated with sustainable forest management is one approach to setting thresholds. The other involves establishing ranges of natural variability (Utzig and Holt 2002).

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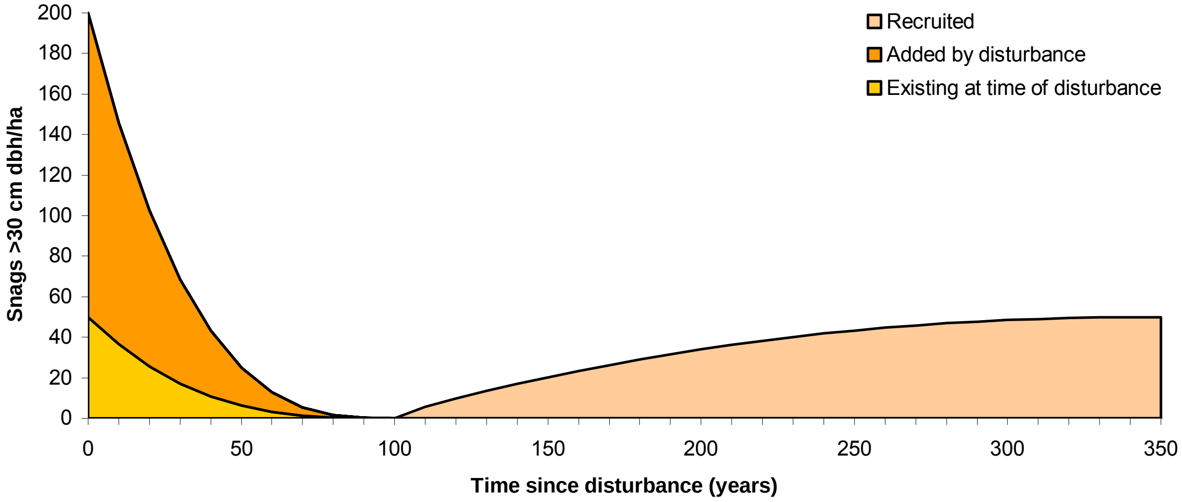
# Appendix I. Models of Habitat Element Dynamics

## Snags: ESSFwc Natural Stands



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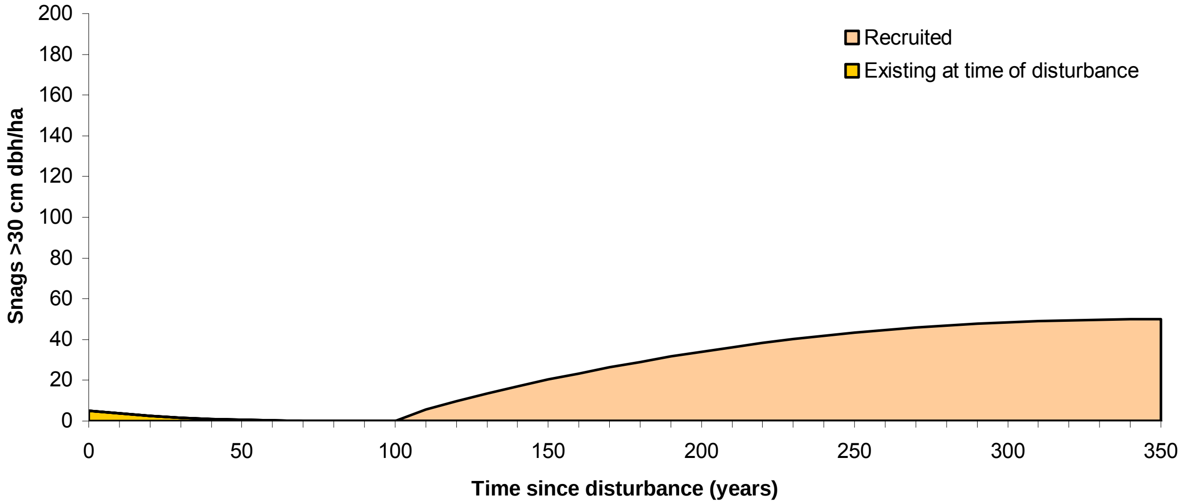

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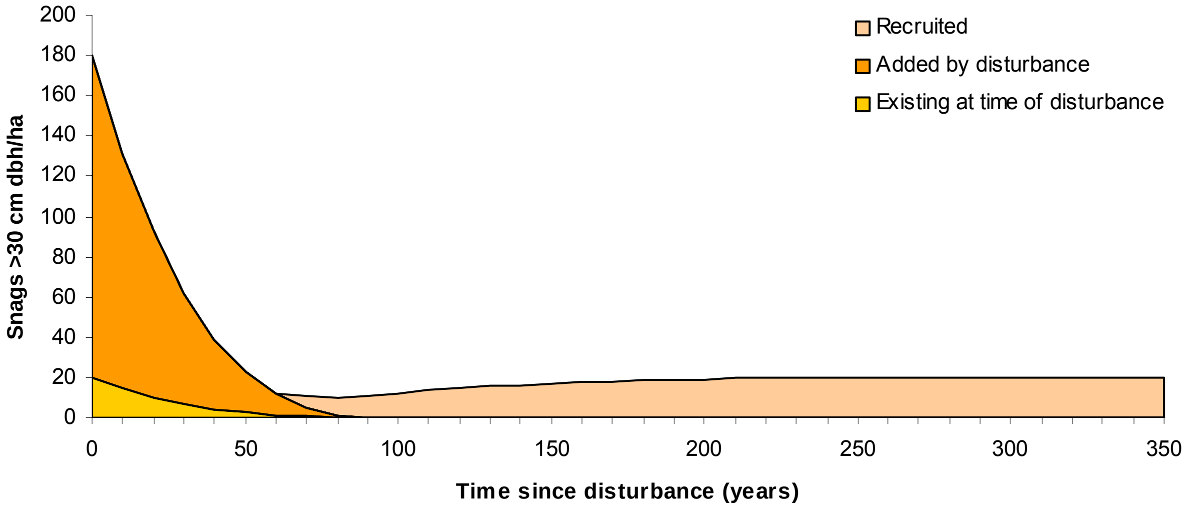

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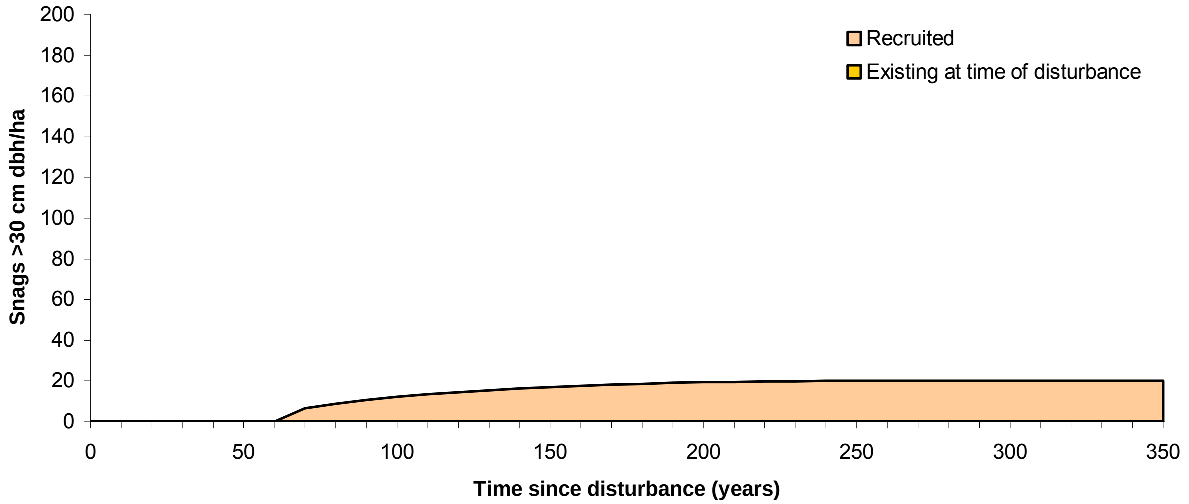

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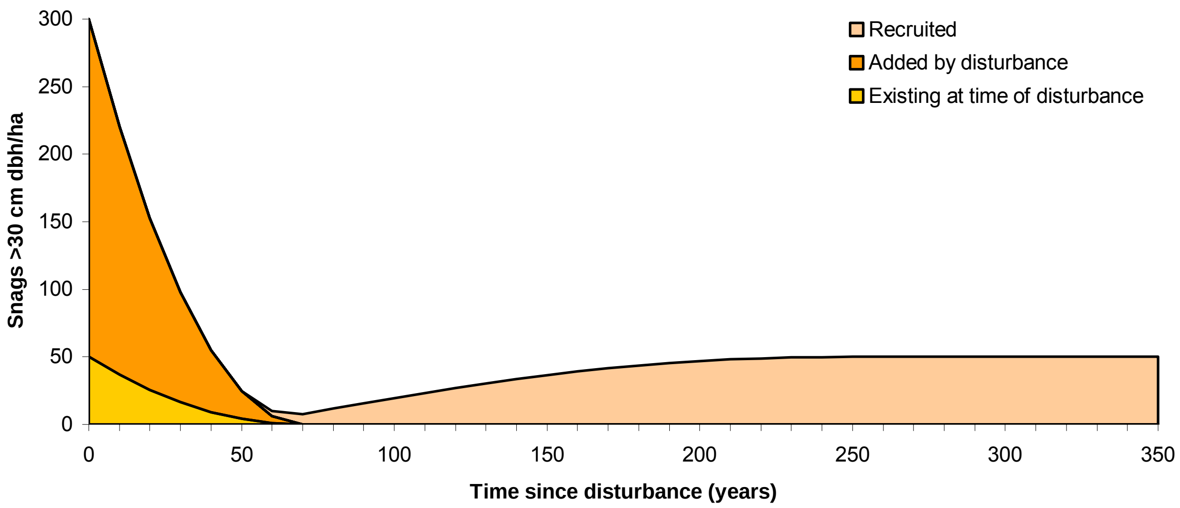

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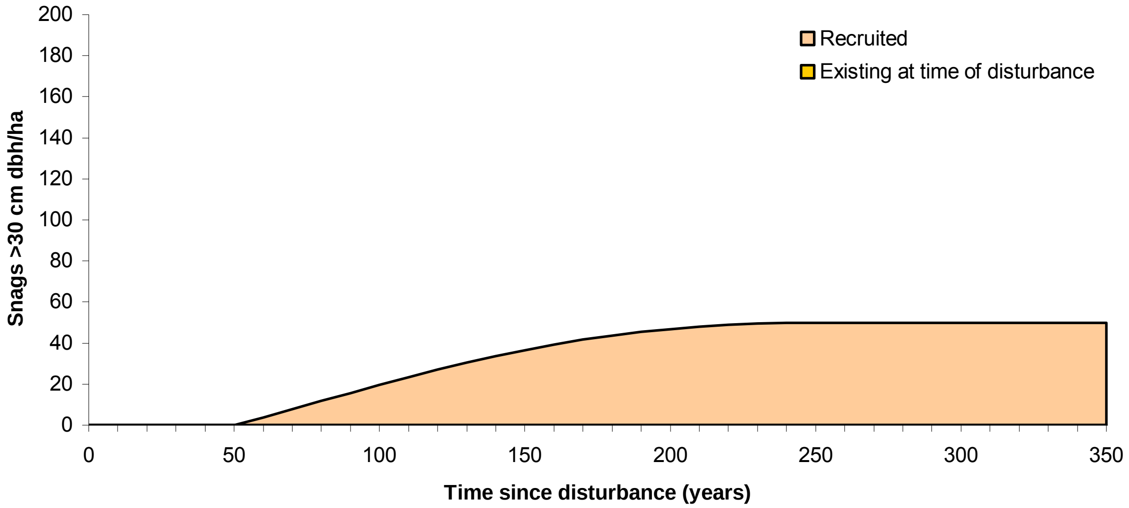
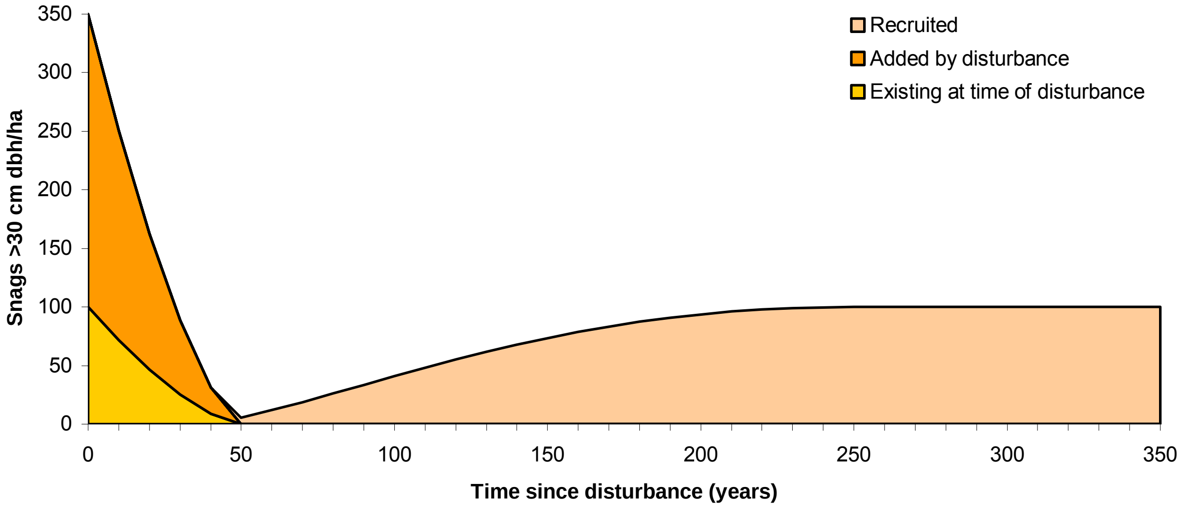


## Snags: ICHwk Natural Stands



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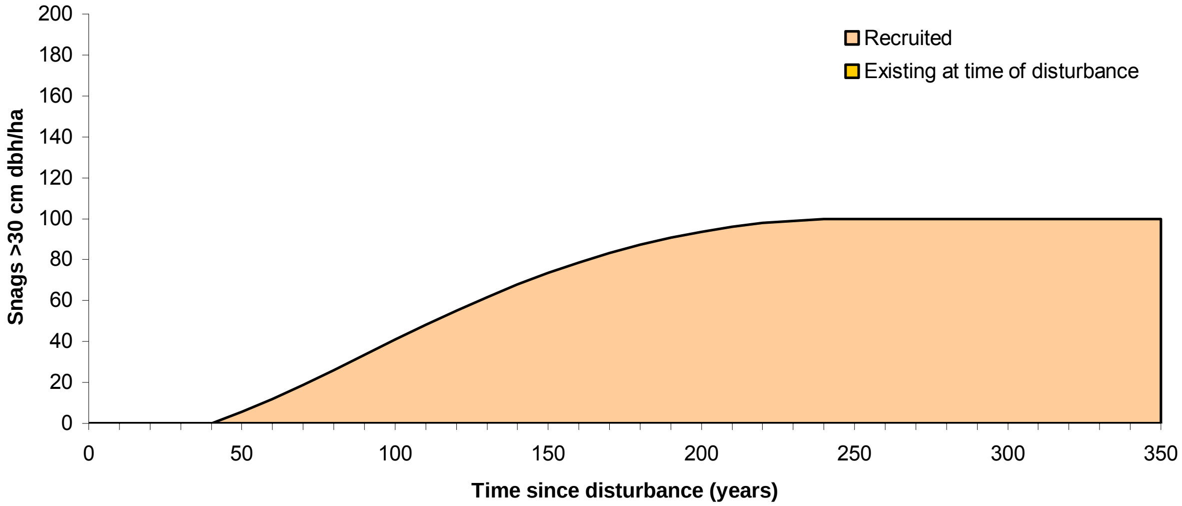

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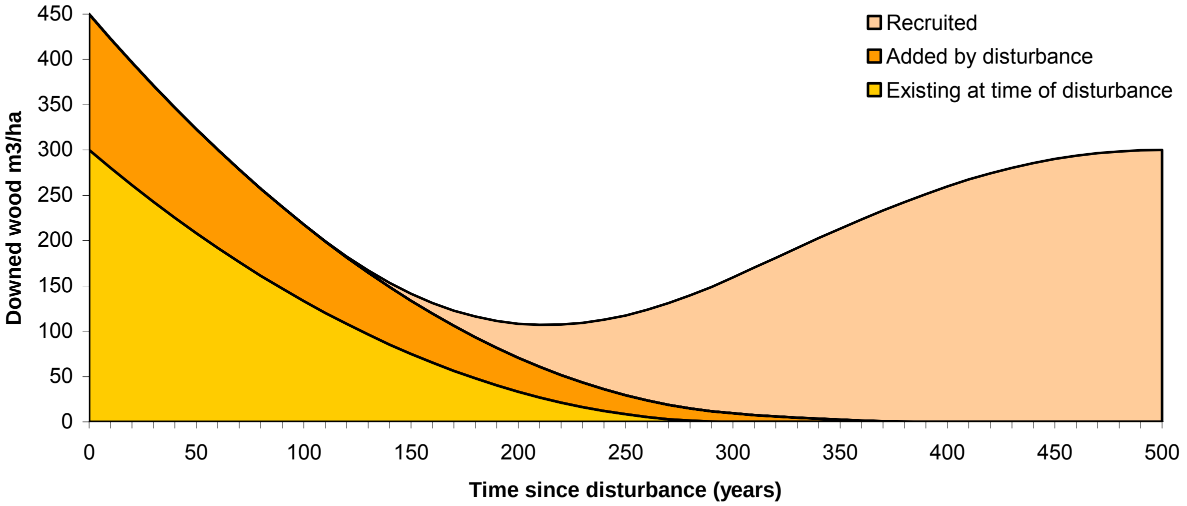

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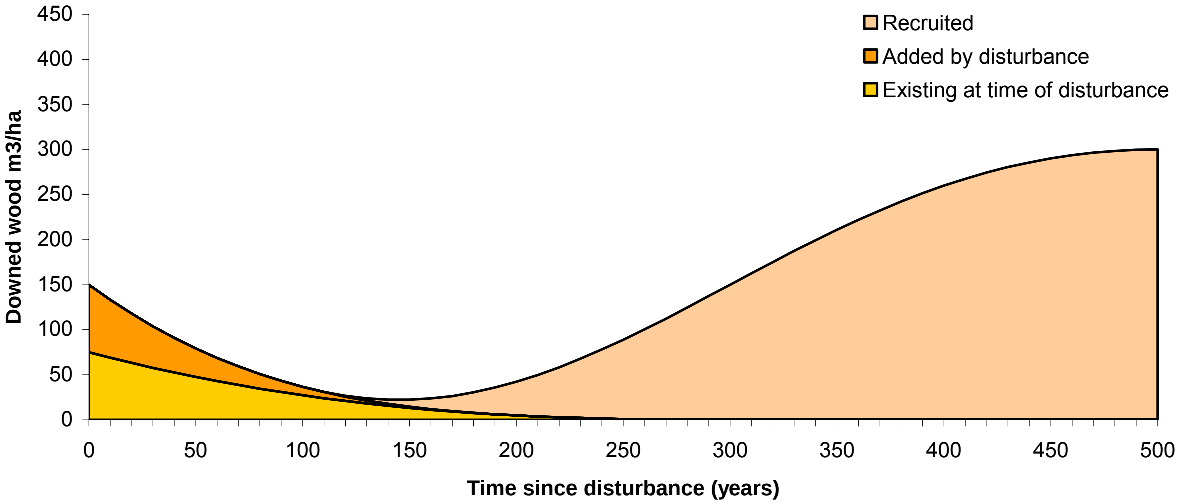

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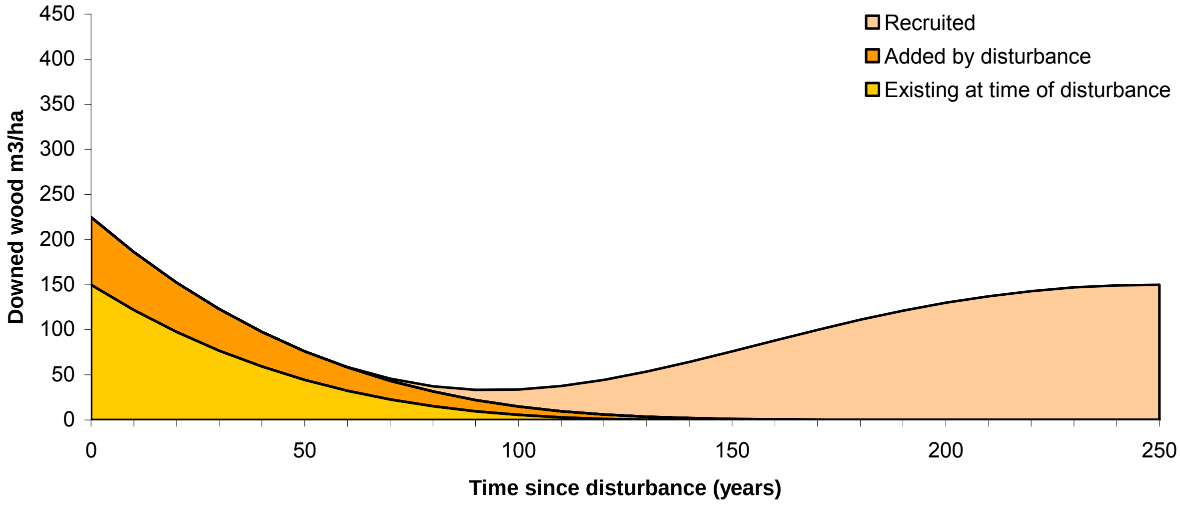
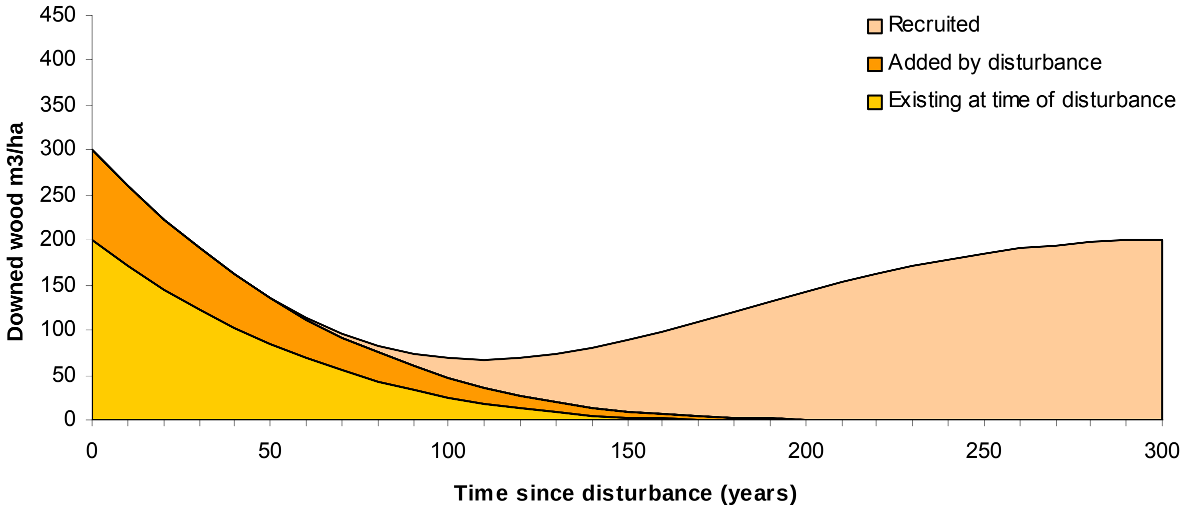
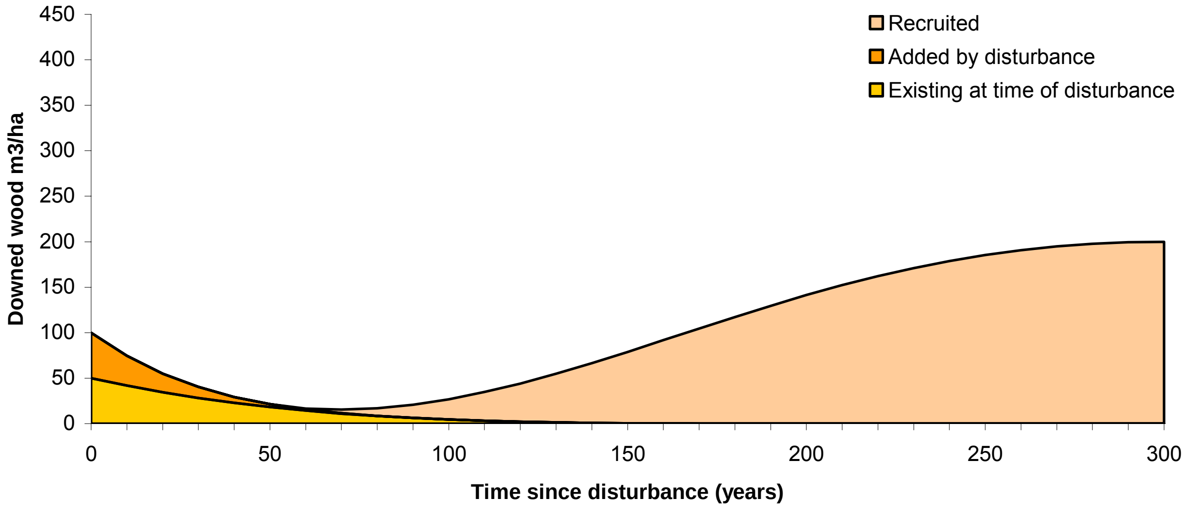


Downed Wood: ICHdw Harvested Stands

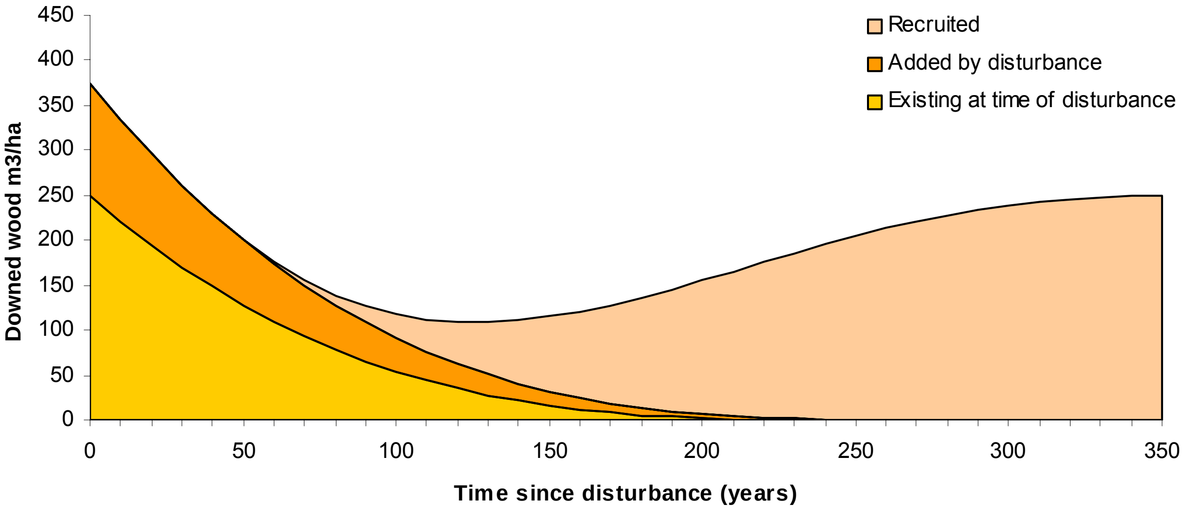
## Downed Wood: ICHmw Natural Stands



## Downed Wood: ICHmw Harvested Stands



Downed Wood: ICHwk Natural Stands



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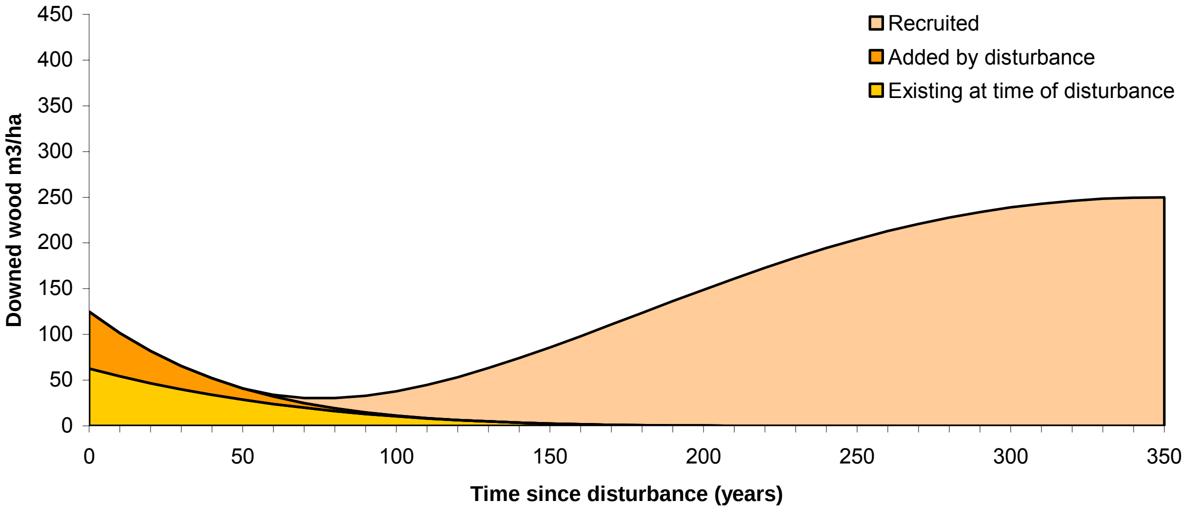
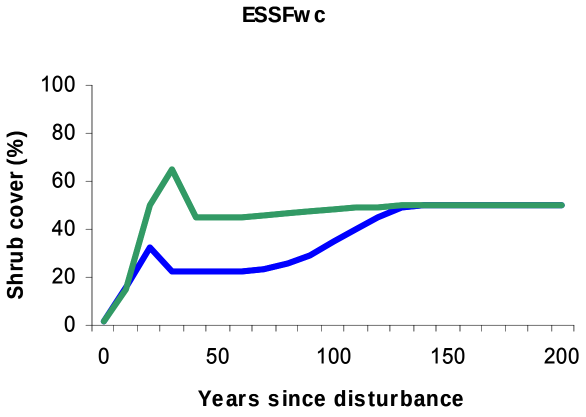
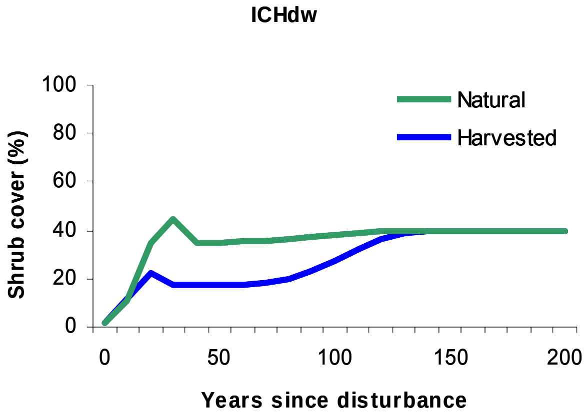
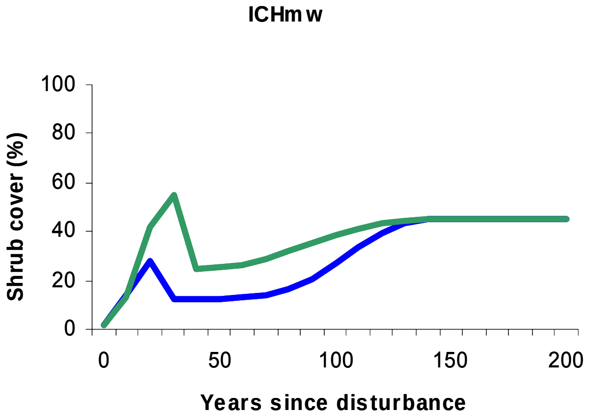
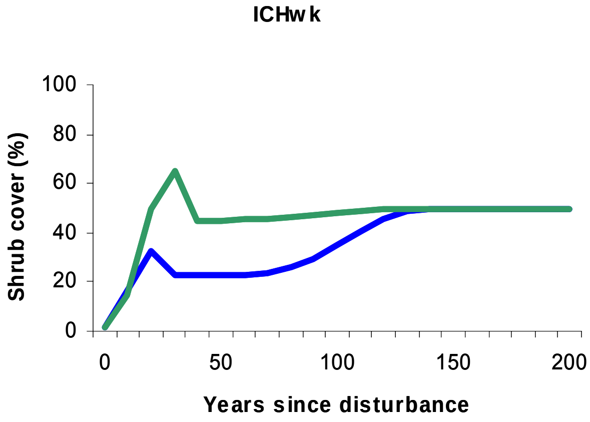


## Shrub Cover (%)









## Hardwood Abundance (% composition): Natural Stands