Prognosis^{BC} Calibration in the IDFdm2,

Invermere Forest District:

Field Sampling and Preliminary Results

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Executive Summary

This report summarizes the collection of field data in the Kootenay Dry Mild Interior Douglas-fir variant (IDFdm2) within the Invermere Forest District. Sampling for the calibration of the Prognosis^{BC} model followed the methods used in previous research in southeastern British Columbia. Additional measurement for substrate and spatial attributes was based on research by LePage *et al* (2000). Field sampling was completed during the 2001 (May to August) field season.

A total of 111 plots were sampled from 37 polygons. On 25 of these plots additional measures of substrate and spatial attributes were obtained. The target of sampling 80 percent in partial cut areas, 10 percent in clearcuts, and 10 percent in undisturbed stands was achieved. The plots provide a good range of aspects, elevations, geographic locations, and site series. Since the IDFdm2 sites occur on mid- to low- slope areas, the range for slope is restricted.

Preliminary analyses indicate that residual basal area has some effect on both five-year height growth of small trees and average height growth of regeneration. Site series does not appear to have a clear effect, but may be interacting with other site factors. Regeneration abundance does not show a relationship with residual basal area. Modal site series may have higher overall abundances of regeneration. In all cases, Douglas-fir is the dominant species, while other species contribute a minor component. Lodgepole pine is prevalent in planted sites, which correlates with low residual basal area values.

A meeting in November 2001 in Invermere, BC provided the opportunity for extension of early results to Ministry and industry stakeholders. Feedback is being incorporated into analysis. A poster, entitled "Prognosis^{BC} Modelling at the University of British Columbia", was presented at the Second Forest Vegetation Simulator (FVS) Conference, Fort Collins, Colorado, February 12-14, 2002 and at the University of British Columbia Forestry Research Evening, March 5, 2002. A web site has also been created for extension purposes.

Calibration of the small tree height growth model is underway. Imputation methods will be used to predict regeneration rather than calibration of the regeneration establishment component of the Prognosis^{BC} model.

Acknowledgements

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[1] *Funding assistance by Forest Renewal BC does not imply endorsement of any statements or information contained herein.*

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Introduction

The Prognosis[BC] model was developed to predict the growth and yield of multi-species and multi-aged stands. The lack of viable natural regeneration and small tree growth components limit applications of the existing version of this model. Several projects have been initiated to obtain the data needed to model small tree growth and regeneration (Boisvenue 1999; Lencar and Marshall 2000; and Hassani and Marshall 2001).

The Interior Douglas-fir (IDF) biogeoclimatic zone occupies the rolling hills and valley terrain of the southern interior plateau of British Columbia (Hope *et al.* 1991). The zone accounts for approximately 5% of the British Columbian landscape (Ministry of Forests 1995), and is characterized by warm, dry summers and cool winters, with a relatively long growing season (Hope *et al.* 1991). Rainshadow effects are an important climatic factor. Climax stands are comprised mainly of Douglas-fir (*Pseudotsuga menziesii var. glauca* (Mirb.) Franco) solely, or mixed with other species.

Two variants of the IDF occur in the Invermere Forest District: the IDFun (Undifferentiated Interior Douglas-fir (Windermere Lake) Unit) and the IDFdm2 (Kootenay Dry Mild Interior Douglas-fir Variant). The IDFun occupies a small area that is mainly on private land (Braumandel *et al.* 1992), and was not targeted for Prognosis[BC] calibration.

Within the Invermere Forest District, the IDFdm2 is located in the valley bottoms and lower slopes of the Rocky Mountain Trench, and in the valley bottoms of the major tributary rivers, such as the Findlay, Spillimacheen, and Kootenay Rivers (Braumandel *et al.* 1992). Douglas-fir is the dominant species, however Ponderosa pine (*Pinus ponderosa* Laws.), lodgepole pine (*Pinus contorta var. latifolia* Dougl.), western larch (*Larix occidentalis* Nutt.) and hybrid white spruce (*Picea glauca x engelmannii*) are also common. Other species occur infrequently. Table 1 is a complete list of tree species, scientific names, and species codes referred to in this report.

The IDFdm2 ranges in elevation from 800 to 1200 m on south aspects, and from 800 to 1100 m on north aspects. This is an important area for cattle grazing and wildlife. The IDFdm2 generally extends into the Dry Cool Montane Spruce (MSdk) at higher elevations and the Dry Hot Ponderosa Pine (PPdh) at lower elevations. The extent of the IDFdm2 within the Invermere Forest District is illustrated in Figure 1.

Table 1. Local name, scientific name, and species code for trees of the IDFdm2.

Local Name	Scientific Name	Code
Douglas-fir	*Pseudotsuga menziesii var. glauca* (Mirb.) Franco	Fd
Hybrid spruce	*Picea glauca* (Moench) Voss *x Engelmannii* Parry	Sxw
Lodgepole pine	*Pinus contorta var. latifolia* Dougl.	Pl
Paper birch	*Betula papyrifera* Marsh.	Ep
Ponderosa pine	*Pinus ponderosa* Laws.	Py
Rocky Mountain Juniper	*Juniperus scopulorum* Sarg.	Rj
Subalpine fir	*Abies lasiocarpa* (Doug.) Lindl	Bl
Trembling aspen	*Populus tremuloides* Michx.	At
Western larch	*Larix occidentalis* Nutt.	Lw

The purpose of this research is to calibrate the small tree height growth model and to provide inputs and/or models for regeneration components of Prognosis^{BC} in the IDFdm2 subzone variant of the Invermere Forest District, British Columbia, for a variety of harvesting regimes. In this report, the data collection procedure for the IDFdm2 subzone variant is presented.

Methods

The sampling procedure for collecting data for the small tree and regeneration components of Prognosis^{BC} was initially designed by Boisvenue (1999), based upon methods originally outlined by Ferguson and Crookston (1991). Field sampling completed in subsequent years in southeastern BC (Lencar and Marshall 2000, Hassani and Marshall 2001) incorporated refinements to the design. The sampling strategy for the 2001 field season incorporated further refinements based on results from this research, as well as an additional, exploratory component, which involved additional measurements for spatial attributes and substrate type.

Sampling Frame and Site Selection

The sampling frame consisted of all areas located within the IDFdm2 biogeoclimatic subzone of the Rocky Mountain Trench, Invermere Forest District, which had been disturbed (harvested) within the last 5-25 years. In addition, undisturbed sites were also identified. Sites were included in the sampling frame regardless of ownership, but selection was based on accessibility. Site selection was restricted to those sites located within a two hour driving radius of Invermere, BC, in order to minimize cost and maximize time efficiency. Sampling effort focused on selecting: 80% partially cut (shelterwood, seed tree, and selection silviculture systems), 10% undisturbed (selected purposively based on similarities in site characteristics to those in partially cut stands) and 10% clearcut stands.

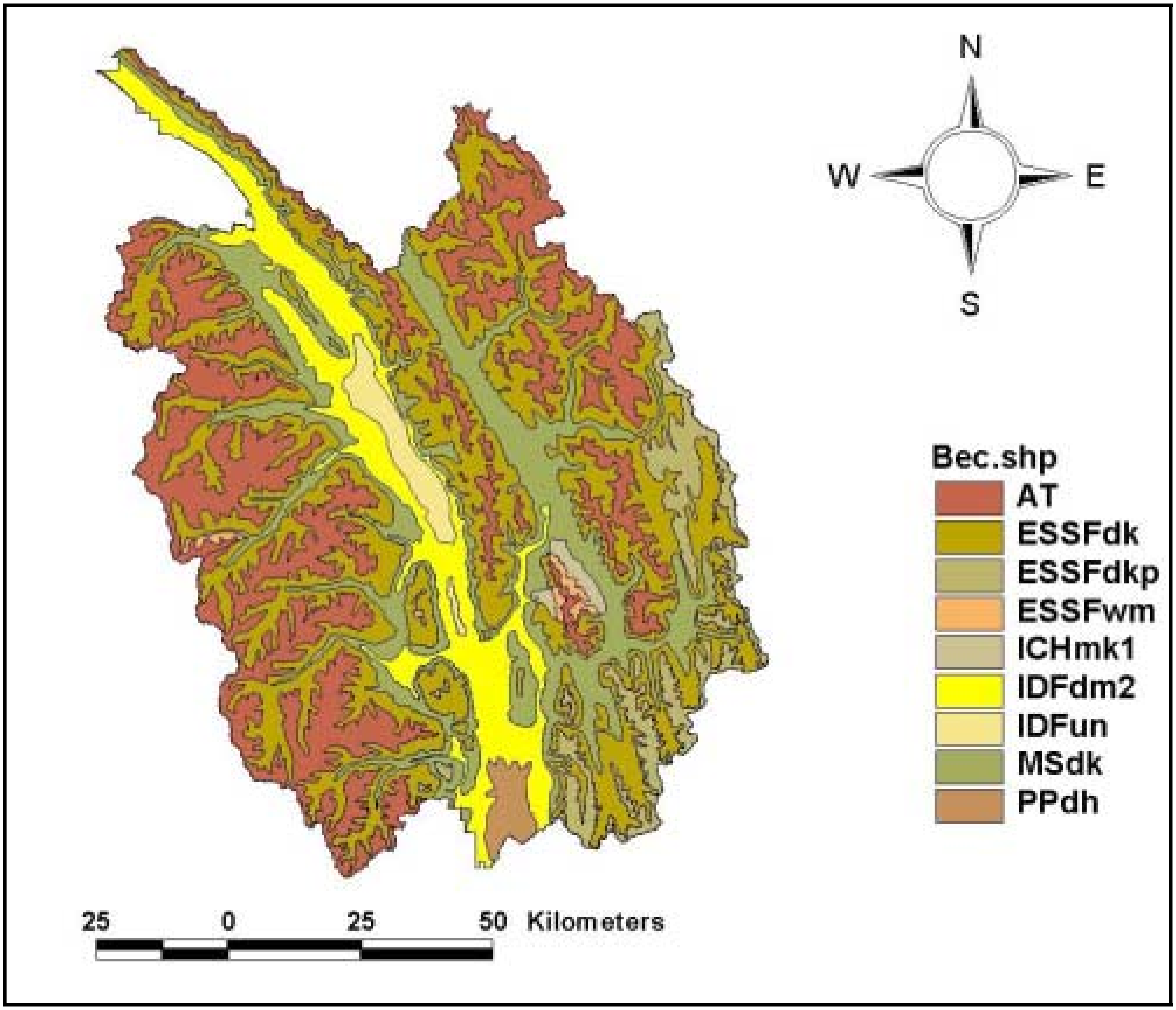

Figure 1. Location of biogeoclimatic variants within the Invermere Forest District

*** AT** = Alpine Tundra Zone; **ESSFdk** = Engelmann Spruce/Subalpine Fir Dry Cool Subzone; **ESSFdkp** = Engelmann Spruce/Subalpine Fir Dry Cool Parkland Subzone; **ESSFwm** = Engelmann Spruce/Subalpine Fir Wet Mild Subzone; **ICHmk1** = Kootenay Moist Cool Interior Cedar Hemlock Variant; **IDFdm2** = Kootenay Dry Mild Interior Douglas-fir Variant; **IDFun** = Undifferentiated Interior Douglas-fir Unit; **MSdk** = Dry Cool Montane Spruce Subzone; **PPdh**= Kettle Dry Hot Ponderosa Pine Variant

A sampling matrix was set up to aid in site selection of disturbed stands. The sampling matrix categorized openings based upon number of years since disturbance, silvicultural system, BEC site series, and elevation. There were 256 matrix categories (combinations of year since disturbance, silvicultural system, BEC and elevation) based upon these classification criteria (see Table 2). Data provided by the Ministry of Forests from their ISIS (Integrated Silviculture Information System) database was used to identify 333 candidate openings that were harvested within the last 5-25 years. Openings were removed from the candidate list if they had any of the following attributes:

1. missing BEC site series, disturbance type, silvicultural system, or elevation;
2. less than four ha in size; and
3. marked as “burned” or “wildfire”.

The remaining 232 openings were classified as potential sites for data collection, and were categorized into the sampling matrix (Table 2). These openings covered a range of 75 matrix categories. In order to sample the full range of conditions within the cost and time limitations, a maximum of one opening per available matrix category was selected for sampling.

Because the IDF runs north to south along the Rocky Mountain trench, a geographic [climatic] gradient from north to south was expected. In addition, the western side of the valley was generally on the lee slopes of the mountain ranges, and the eastern side was generally on the windward slopes. Therefore, in addition to ensuring that the appropriate polygons were selected based upon the sampling matrix criteria, selection was directed towards obtaining a range of geographic locations and aspects.

Each selected opening was assessed in the field as to suitability. Unsuitable openings were discarded and new openings were selected, and the sampling matrix was adjusted accordingly. In some cases, no suitable openings could be found within a given category.

Preliminary selection was by opening, since this is how the information was summarized in the ISIS database; however, sampling was based on polygons. Once an opening was selected, the number of polygons within the opening were determined. Where a single polygon existed, that polygon was sampled. Where there was more than one polygon, the largest polygon was selected for sampling. Where no single polygon was of an acceptable size (one that would allow a minimum of two plots to be sampled at 100m spacing, without being within 50m of adjacent opening boundaries), an alternate opening was selected.

Within selected polygons, plots were established using systematic sampling with a random start. The number of plots was based upon the degree of variability present and the size of the polygon, with a minimum of two plots per polygon. More variable (heterogeneous) polygons were sampled more intensively. Plots were established at a minimum distance of 50 m from roads or other openings, in order to avoid the effects of edge. Plots were established 100 m apart within the polygon. Sampled polygons are listed in Table 3.

Table 2. Number of available openings in the IDFdm2, Invermere Forest District, by elevation, site series, and harvesting system.

	SILVICULTURE SYSTEM																
	Clearcut/Patch				Selection				Shelterwood				Seed Tree				
Years Since Dist.	Elevation				Elevation				Elevation				Elevation				
Site Series	0 to 900	901-1000	1001-1100	1101+	0 to 900	901-1000	1001-1100	1101+	0 to 900	901-1000	1001-1100	1101+	0 to 900	901-1000	1001-1100	1101+	
5 to 10 (1991-1996)																	Total
02																	0
03		4									1						5
01	2	2	1		2	2	8	2	1	2	3		2			1	28
04			1			2				5				1			9
11 to 15 (1986-1990)																	
02																	0
03			1						1								2
01		1	5	2	8	4	6	3		2			2		5	4	42
04			1			2	1			1		1		1	1		8
16 to 20 (1981-1985)																	
02								1									1
03								1									1
01			6		10	12	11	4						3	4	4	54
04	1			1		2	3					1		2	3	2	15
21 to 25 (1976-1980)																	
02						1	2										3
03							3										3
01		2	2	1	3	7	17	4							1	1	38
04		1	6		1	5	5	4						1			23
Total	3	10	23	4	24	37	56	19	2	10	4	2	4	8	14	12	232

Table 3. Selected openings in the IDFdm2, Invermere Forest District, by elevation, site series, and harvesting system.

	SILVICULTURE SYSTEM															
	Clearcut/Patch				**Selection**				**Shelterwood**				**Seed Tree**			
Years Since Dist.	**Elevation**				**Elevation**				**Elevation**				**Elevation**			
Site Series	0 to 900	901-1000	1001-1100	1101+	0 to 900	901-1000	1001-1100	1101+	0 to 900	901-1000	1001-1100	1101+	0 to 900	901-1000	1001-1100	1101+
5 to 10 (1991-1996)																
02																
03											82K080/21					
01						82K060/46	82G092/121				82J022/60		82G092/124			
04			82K089/20							82J032/29				82J032/30		
11 to 15 (1986-1990)																
02																
03			82J002/18						82G092/106							
01						82J002/58				82K070/56			82K070/55	82G081/60		82K069/60
04							82K070/48			82K079/55					82K079/94	82K010/11
16 to 20 (1981-1985)																
02																
03																
01			82K069/56	82J012/28	82G071/52	82K070/27								82K069/52	82J022/28	82J012/33
04							82J012/16									
21 to 25 (1976-1980)																
02																
03							82J011/10									
01			82K079/21		82K070/03		82K020/40									
04								82K059/26								

Sampling Methods

Data for Calibration of Prognosis[BC]

The location of each plot was recorded using a portable Geographic Position System (GPS) unit, and the following attributes were documented:

1. Mapsheet, opening number, polygon number, and plot number;
2. Latitude and longitude;
3. Aspect (degrees);
4. Slope angle (percent);
5. Slope position;
6. Elevation;
7. BEC site series and associated ecological factors (i.e. partial vegetation list);
8. Site preparation method (where identifiable);
9. Disturbance information (where available);
10. Disturbance year; and
11. Other information where deemed important (e.g. grazing intensity if cattle present).

Trees in each plot were categorized as large trees, small trees, or regeneration. Large trees were defined as having a dbh greater than 7.5 cm; small trees were defined as having a dbh between 2.0 and 7.5 cm. Regeneration was defined based upon both dbh and height, where shade tolerant species were required to be at least 15 cm tall and less than 7.5 cm dbh, and shade intolerant species were required to be at least 30 cm tall and less than 7.5 cm dbh (Ferguson *et al.* 1986; Ferguson and Carlson 1993).

Large trees were measured within an 11.28 m radius plot (0.04 ha). Information on species and dbh was recorded, in order to identify species composition in the overstory and to estimate retention level and residual basal area to enable the study of the impact of residual cover on regeneration (advance and subsequent) growth, and the establishment of new seedlings. Where numbers allowed, two trees from each species were randomly selected and measured for height. Tree health information (pests, pathogens, crooks, and so on) was recorded as necessary.

Small trees were measured within the same 11.28 m radius plot, in order to maintain consistency with other Prognosis[BC] research completed in the IDF (e.g., Lencar and

Marshall 2000). Species and dbh were recorded for each tree. Where numbers allowed, five trees of each species were subsampled for total height and five-year height increment. The five-year height increment was measured starting five years prior to the end of the previous growing season, so that the same period of growth (five full seasons) was measured for each tree. Where possible, whorls were used to determine five-year height growth. Where whorls could not be confidently counted (e.g. for non-determinant species and for some determinant trees), the trees were felled for measurement, and then sectioned until the five-year increment was reached. Additional tree health information was again recorded as necessary.

Regeneration was sampled by placing a 2.07 m radius plot (0.00135 ha) at the center of the 11.28 m radius plot. All established and viable regeneration was counted and tallied into height classes as follows:

Class 1: 15-49.95 cm (shade tolerant species only)

Class 2: 49.95-99.95 cm

Class 3: 99.95-129.95 cm

Class 4: >129.95 cm

Regeneration was also marked as advance or subsequent, in order to be able to better predict establishment of regeneration following disturbance, and to better understand the growth of both types of regeneration. See Appendix A for the methods used to distinguish between these two types of regeneration.

A subsample of exact height and total age was taken for both "best trees" (seedlings) and randomly selected seedlings within the plot. "Best trees" were defined by Ferguson and Carlson (1993) as:

1. the two tallest seedlings, regardless of species;
2. the one tallest seedling of each additional species present; and
3. the tallest of the remaining seedlings until at least four were sampled.

Where numbers allowed, two seedlings of each species were randomly selected and sampled as "random trees". Again, where whorls could not be confidently counted, seedlings were destructively sampled. Seedling health was noted as required.

Four additional 2.07 m radius regeneration plots were established at 11.28 m from the plot center (along the large plot boundary), in the cardinal directions. Within each satellite plot, regeneration was tallied by species, height class, and regeneration type (advance or subsequent). Where the center (regeneration) plot was not stocked, one of the four satellite plots was selected randomly until a stocked satellite plot was located. This plot was then used for height and age sampling.

Spatial and Substrate Measurements

One out of four plots sampled (generally, one plot for every one or two polygons) was selected for additional measurements of substrate and spatial attributes. The design for this component of the sampling strategy was loosely based upon LePage *et al.* (2000), and modified for use with circular plots. The goal of this addition was to explore whether spatial attributes or information on substrate type could aid in refining the understanding of regeneration in IDFdm2.

Substrate Measures

In order to examine the relationship between substrate type and regeneration, regeneration was then tallied by height class, species, and the substrate it occurred on, and classified as advance or subsequent regeneration. Germinants, defined as less than 15 cm for shade tolerant species and less than 30 cm for shade intolerant species, were also tallied. Substrate measures were taken before any other measurements, to ensure that the substrates experienced minimal disturbance prior to sampling. The center regeneration plot was used regardless of whether it was "stocked" or not. This plot was then divided into quadrants (using cardinal directions), and the percent cover by different substrates was estimated for each quadrat. Substrates were defined as follows:

1. Mineral soil – bare soil or soil with discontinuous litter cover <1 needle thick;
2. Litter – continuous cover >1 needle thick (needles, cones, etc.);
3. Kinnikinnick – relatively continuous cover with/without needle litter;
4. Grass Discontinuous – discontinuous cover ("bunchy" or scattered distribution);
5. Grass Continuous – continuous cover;
6. Moss – continuous moss cover;
7. Lichen crust – continuous lichen crust;
8. Slash – woody debris <17.5 cm;
9. Stump – includes 10 cm radius immediately around stump;
10. CWD – woody debris >17.5 cm;
11. Shrub – occupied by shrubs (list by species and record average height);
12. Rock – exposed rock;
13. Tree – existing stem (live or dead);
14. Organic – organic materials; and
15. FWD – decayed slash/coarse woody debris which still retains some structure.

Spatial Measures

For spatial attributes, the goal was to obtain information necessary to examine the relationship of regeneration to canopy gaps and response to silvicultural treatments such as tree removal. In particular, to look at the spatial arrangement of regeneration "clumps" as they occurred within the plot. Spatial mapping occurred within the 11.28 m radius plot used for small and large tree sampling (Prognosis^{BC} calibration). Distance and bearing were taken for all large trees, to the front of each stem, at dbh using a Criterion laser. Distance to stem center could later be calculated by adding the radius of the tree to the distance to the front of the stem.

Regeneration clumps were identified in the field using the following definition:

1. A minimum of 3 trees was required to be considered a clump (from regeneration classes 1 to 4);
2. Membership in a clump occurred if: for classes1-3, the stem was within 0.5 m of a stem belonging to the clump; for class 4, the stem was within 1.0 m of a stem belonging to the clump; and
3. The shape of the clump was assumed to be ellipsoidal for the purposes of measurement and plotting.

The definition of small trees, as measured during the Prognosis^{BC} calibration sampling component, overlaps with that of regeneration. For the purposes of measuring the regeneration plot (2.07 m), a regeneration tree was defined as less than 7.5 cm dbh. For the purposes of measuring the small tree plot (11.28 m), a small tree was defined as a tree with dbh between 2.0 and 7.5. When spatially mapping, small trees were technically regeneration as well. Since time was a limiting factor, small trees were not mapped. Instead, small trees located within regeneration clumps were considered part of that clump. All other small trees were mapped individually in the same manner as large trees.

Distance and bearing to the center point of the clump were measured. The long and short axes (based on an elliptical shape) were measured to obtain the size of the clump, and the bearing of the long axis was taken to establish the orientation of the clump. To be included in sampling, the center of the clump had to be within the 11.28 m radius; however, it was measured to its full extent, regardless of whether or not it extended beyond this boundary. Within each clump, regeneration was tallied by species and height class, and classified as subsequent or advance. Where a large clump visually appeared to be composed of two distinct clumps (e.g. a patch of class four regeneration plus a patch of class one regeneration), it was sampled as two separate clumps and noted as such.

Additional information on slash piles, large clumps of shrubs, windthrow, and stumps was recorded as well. Large slash piles were recorded in a manner similar to regeneration clumps. Bearing and distance to the center of the pile were taken, and then width and length (based on an ellipsoidal shape) were measured, along with the orientation (bearing) of the pile itself. Large clumps of shrub (generally, common juniper) were recorded in the same way. Both required that their center fell within the

11.28 m radius. Windthrow was mapped if its point of germination fell within the 11.28 m radius, and its dbh was greater than or equal to 17.5 cm. For windthrow, bearing and distance were taken to the origin (point of germination) of the tree, and then dbh, length and bearing of tree axis were measured. Stumps (5 cm diameter or greater) were also mapped. Distance and bearing to the center of the stump and dbh were recorded. Standing dead trees (dbh greater than or equal to 7.5 cm) were recorded for dbh and mapped using distance and bearing to the front of the stem.

Distribution and Number of Plots

Data collection commenced in May of 2001 in the Invermere Forest District. A total of 37 polygons were sampled between May 1 and August 31, 2001 – 32 from disturbed stands and 5 from undisturbed stands. A total of 111 plots were sampled for Prognosis^{BC} calibration. Spatial sampling and substrate data was collected on a total of 25 plots. Figure 2 shows the location of the sampled polygons and Table 4 provides ranges for selected variables.

Site series 01 was separated into three categories: 03/01, 01 and 04/01. It was found that there were drier and wetter sites, which were not classifiable into 03 or 04, but were different from the most typical 01 sites. Analysis will show whether or not this distinction is important. No site series 02 sites were found during field sampling, even though some were identified in the ISIS database information.

The target of 80 % sampling effort in the partially cut areas was achieved: 89 partial cut plots out of 111 total plots were sampled. Roughly 1/3 of the plots were taken from each partial cutting type (selection, shelterwood, and seed tree systems). Slightly fewer shelterwood sites were selected due to poor availability of sites in older age classes. Clearcut and undisturbed stands each accounted for 10 percent of the total number of plots.

Sites that were classed by the ISIS database as less than or equal to 900 m in elevation were often slightly higher, resulting in few plots in that category. In the other three elevation classes, there was a good distribution of plots. There was also a good distribution of plots from north to south, by slope position, and by aspect. Slopes were generally low in most plots.

Table 4. Number of plots summarized by variable classes.

Plots By Site Series:	
02	0
03	15
01/03	10
01	40
01/04	25
04	21

Plots By Location:	
North	31
South	47
Central	33

Plots By Elevation (m):	
0-900	4
901-1000	46
1001-1100	37
1101+	24

Plots By Slope Position:	
Flat	20
Crest	14
Upper	20
Mid	29
Lower	19
Toe	3
Depression	6

Plots By Silviculture System:	
Clearcut	11
Selection	38
Shelterwood	21
Seed Tree	30
Undisturbed	11

Plots By Aspect:	
None/Variable	27
N	11
NE	6
E	12
SE	17
S	6
SW	8
W	13
NW	11

Plots By Slope (Percent):	
0 (variable)	11
0-10	45
11-20	35
21-30	10
31-40	6
41-50	3
51-60	1

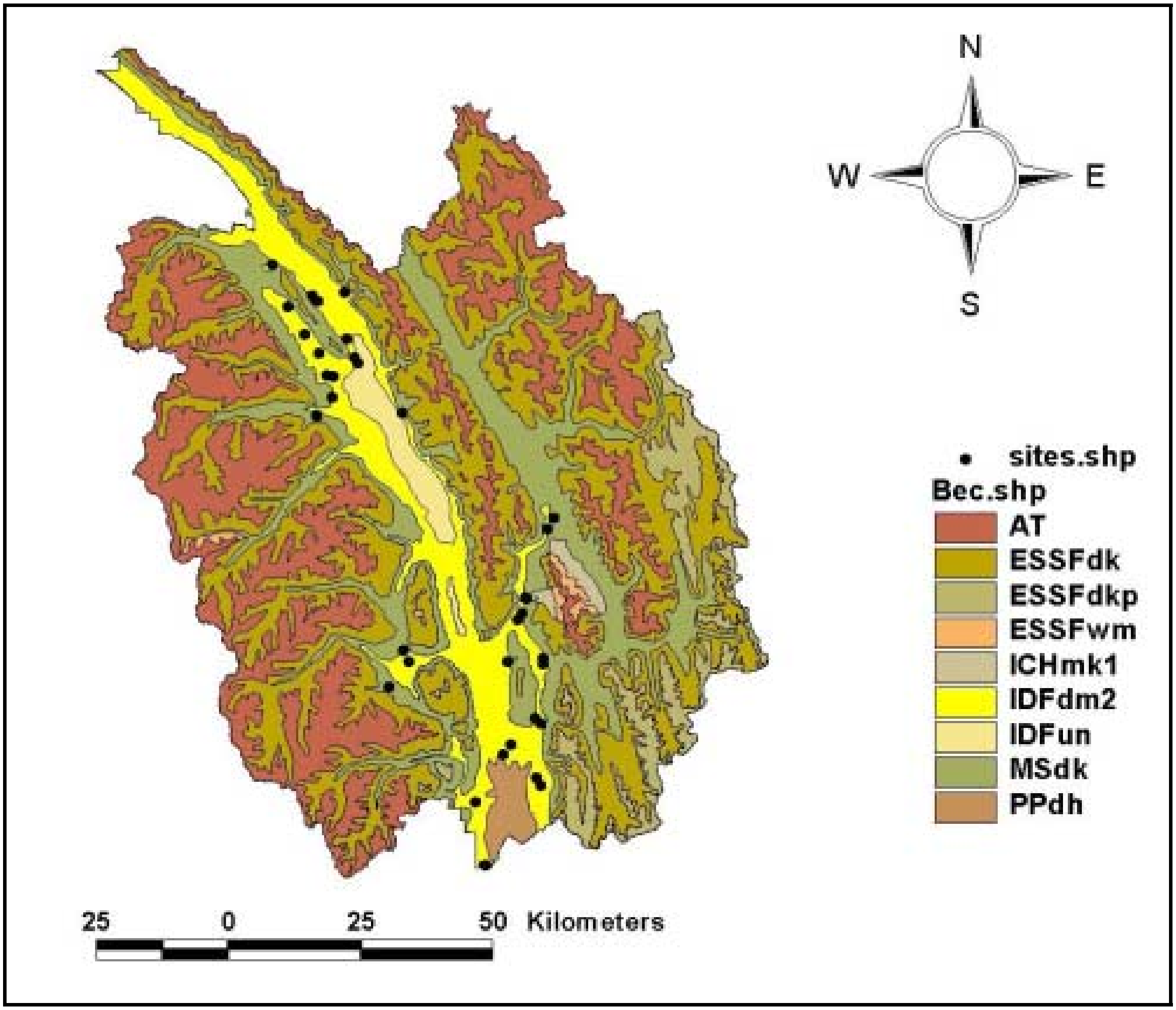

Figure 2. Location of polygons sampled in summer 2001.
*** AT** = Alpine Tundra Zone; **ESSFdk** = Engelmann Spruce/Subalpine Fir Dry Cool Subzone; **ESSFdkp** = Engelmann Spruce/Subalpine Fir Dry Cool Parkland Subzone; **ESSFwm** = Engelmann Spruce/Subalpine Fir Wet Mild Subzone; **ICHmk1** = Kootenay Moist Cool Interior Cedar Hemlock Variant; **IDFdm2** = Kootenay Dry Mild Interior Douglas-fir Variant; **IDFun** = Undifferentiated Interior Douglas-fir Unit; **MSdk** = Dry Cool Montane Spruce Subzone; **PPdh**= Kettle Dry Hot Ponderosa Pine Variant

Preliminary Results

The field data were subjected to a thorough cleaning and reorganization, to ensure that all data entry was complete and correct.

Small Tree Height Growth

The majority of trees were Douglas-fir, which occurred in all site series. Other species were found across different ranges of site series, generally according to their environmental and site preferences. Certain species, such as subalpine fir, were extremely rare, while species such as ponderosa pine and western larch indicated specific preferences for site types (Table 5).

Table 5. Number of small trees sampled for height and five-year height growth by site series.

Site	Species								
Series	At	Bl	Ep	Fd	Lw	Pl	Py	Rj	Sxw
03				157			7		
03/01				356		33	4	20	4
01/03	3			322		15	21	3	
01	12			651	51	903	2	10	3
01/04	36	5		478	21	467	3	6	25
04/01		5	4	100	2	11			23
04	79		94	170	2	103			
04/05	54			3		1			
Total	184	10	98	2237	76	1533	37	39	55

A subset of small trees was sampled for five-year height growth (Table 6). Lodgepole pine shows a clear trend of increasing five-year height growth over the range of site series. Douglas-fir shows a less clear trend, where the appearance of increasing five-year height growth over the range of site series is marred by the high growth values at the driest site series. None of the other species exhibit a clear pattern. There is high variability in this data, which may indicate interactions with other factors.

Table 6. Average 5-year height growth (cm) by species and site series.

Site	At			Bl			Ep			Fd			Lw		
Series	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
03										21	91	(57)			
03/01										45	44	(25)			
01/03	3	152	(30)							44	73	(40)			
01	7	133	(21)							128	82	(58)	32	175	(72)
01/04	13	113	(30)	5	62	(86)				81	67	(51)	8	240	(50)
04/01				5	70	(67)	4	131	(17)	23	80	(58)	2	87	(19)
04	24	175	(31)				28	149	(55)	35	125	(62)	2	268	(6)
04/05	10	126	(35)							3	118	(19)			

Site	Pl			Py			Rj			Sxw		
Series	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
03				5	136	(37)						
03/01	21	90	(38)	4	45	(13)	6	42	(9)	3	67	(12)
01/03	7	82	(29)	17	92	(39)	3	60	(11)			
01	79	129	(47)	2	111	(37)	9	39	(17)	3	106	(36)
01/04	55	127	(37)				5	48	(27)	20	56	(32)
04/01	6	155	(61)							12	86	(57)
04	34	152	(36)									
04/05	1	229	-									

* **n** = number of sampled trees; **SD** = standard deviation.

Table 7 also summarizes the five-year height growth of each species, but in this case by basal area of residual large trees (>7.5 cm DBH). All species except trembling aspen and paper birch exhibit decreasing growth as residual basal area increases. Douglas-fir and western larch also show decreasing variability in five-year height growth as residual basal area increases.

Table 7. Average 5-year height growth (cm) by species and basal area class.

BA	At			Bl			Ep			Fd			Lw		
Class	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
1	28	161	(31)	1	214	(214)	25	144	(57)	141	111	(59)	30	221	(62)
2	27	130	(43)	3	103	(70)	5	143	(29)	151	70	(44)	10	125	(33)
3							2	183	(10)	53	45	(26)	4	86	(28)
4	2	157	(35)	6	23	(12)				35	27	(21)			

BA	Pl			Py			Rj			Sxw		
Class	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
1	144	137	(39)	11	121	(34)	9	49	(17)	12	105	(34)
2	56	108	(54)	15	80	(42)	8	55	(12)	12	76	(38)
3	2	86	(63)	2	52	(9)				5	58	(37)
4	1	43	(43)				6	25	(7)	9	24	(7)

* **class 1**: 0-9.95 m^2/ha; **class 2:** 10-19.95 m^2/ha; **class 3:** 20-29.95 m^2/ha; **class 4:** >30 m^2/ha.
* **n** = number of sampled trees; **SD** = standard deviation.

Regeneration Abundance

Average regeneration abundance for all species by years since disturbance, basal area class, and type of regeneration is summarized in Table 8. "Natural" is defined as sites with no planting following harvesting activities, as indicated on the ISIS database. "Planted" means sites which have been planted but also includes any natural regeneration that may have been growing concurrently.

Generally, the lowest regeneration abundances occur under high residual basal areas (greater than 30 m2/ha). There are no clear trends in abundance over time (years since disturbance) or by basal area class. Planted sites exhibit considerable variation in abundance; this may indicate the effect of additional natural regeneration on these sites.

Modal site series (01/03, 01, and 01/04) appear to have higher abundances, although there is considerable variation. Again, abundances on planted sites vary widely (Table 9).

Table 8. Mean regeneration abundance (sph) by years since disturbance and basal area (BA) class.

Years Since Disturbance	Regen Type	BA Class 1	2	3	4
5-9	Natural	2529	3510	3449	2136
	Planted	4807	5188		
10-14	Natural	7499	7747	11598	763
	Planted	3334	10377		
15-19	Natural	5205	10320	8851	1526
	Planted	4273	8469		
20-24	Natural		6806	1984	
	Planted	1068	5455		
Undisturbed	Natural			12615	1259

* **class 1**: 0-9.95 m^2/ha; **class 2:** 10-19.95 m^2/ha; **class 3:** 20-29.95 m^2/ha; **class 4:** >30 m^2/ha.

Table 9. Mean regeneration abundance (sph) by years since disturbance and site series.

Years Since Disturbance	Regen Type	Site Series 03	03/01	01/03	01	01/04	04/01	04	04/05
5-9	Natural			2136	2728	3205		3510	
	Planted				8240	5188	1373		
10-14	Natural	6460	5138	8698	7371	9995			
	Planted	3815			4120	4705		2925	
15-19	Natural	4120	5570	11750	5748	9461	6714	5837	
	Planted		610		5646	4629			
20-24	Natural		6511	4273	10224	1984			
	Planted				1068		7935		2976
Undisturbed	Natural		3357	8927	1526	610	1984	16939	1259

Abundances are summarized by individual species for Douglas-fir, lodgepole pine, and interior spruce in Table 10 by years since disturbance, regeneration type and basal area class. Douglas-fir accounts for a large proportion of the overall regeneration abundance. Lodgepole pine occurs at its highest levels in planted sites, since it is a common species planted in these areas. Western larch appears in both planted and natural sites. Interactions with other factors would help explain the amount of variation found in these numbers. Other species were not summarized for this report, since they were found in low numbers.

Table 10. Mean regeneration abundance (sph) by species, years since disturbance and basal area class.

Species	Years Since Disturbance	Regen Type	BA Class 1	2	3	4
Douglas-fir	5-9	Natural	2245	1831	2869	1831
		Planted	4273	4883		
	10-14	Natural	5908	7207	11521	763
		Planted	845	9461		
	15-19	Natural	3696	9919	8037	1526
		Planted	1892	6562		
	20-24	Natural		5799	610	
		Planted	229	3586		
	Undisturbed	Natural			12615	1240
Lodgepole pine	5-9	Natural	174	0	0	0
		Planted	153	0		
	10-14	Natural	1482	70	76	0
		Planted	1679	610		
	15-19	Natural	390	19	102	0
		Planted	2075	305		
	20-24	Natural		855	0	
		Planted	687	76		
	Undisturbed	Natural			0	0
Interior Spruce	5-9	Natural	0	1526	549	0
		Planted	305	229		
	10-14	Natural	0	23	0	0
		Planted	70	305		
	15-19	Natural	34	19	153	0
		Planted	76	76		
	20-24	Natural		61	1373	
		Planted	76	153		
	Undisturbed	Natural			0	0

* **class 1**: 0-9.95 m^2/ha; **class 2:** 10-19.95 m^2/ha; **class 3:** 20-29.95 m^2/ha; **class 4:** >30 m^2/ha.

Regeneration Growth

Average regeneration growth was calculated using total height and age, for both "best" growth and randomly selected regeneration. The average growth of randomly selected regeneration, by species and site series, is presented in Table 11. The average growth of "best" regeneration is summarized in Table 12. There are no trends in average growth for either table by site series.

Table 11. Average growth (cm/y) of randomly selected regeneration by species and site series.

Site	At			Bl			Ep			Fd			Lw		
Series	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
03										10	5.7	(4.9)			
03/01										16	6.2	(4.5)			
01/03	1	32.8	-							19	5.8	(4.8)			
01	2	9.0	(5.7)							44	5.4	(4.3)	6	18.4	(16.4)
01/04	5	21.3	(14.0)	1	2.5	-				35	5.8	(3.9)	3	24.1	(7.6)
04/01										10	3.4	(1.5)	1	19.7	-
04	6	30.0	12.2				2	18.3	(5.1)	22	7.5	(5.4)	1	20.5	-
04/05	1	32.8	-							2	9.8	(1.5)			

Site	Pl			Py			Rj			Sxw		
Series	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
03							1	6.3	-			
03/01	3	7.0	(3.7)				2	5.3	(4.3)			
01/03	2	10.5	(3.8)									
01	27	19.2	(9.6)							2	3.2	(0.5)
01/04	12	23.2	(10.4)	2	13.9	(0.9)				4	5.1	(3.1)
04/01										3	19.4	(11.2)
04	5	22.3	(4.3)							5	5.6	(1.8)
04/05	1	10.0	-									

* **n** = number of sampled trees; **SD** = standard deviation.

Table 12. Average growth (cm/y) of "best" regeneration by species and site series.

Site	At			Bl			Ep			Fd			Lw		
Series	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
03										19	6.9	(4.7)			
03/01										25	6.7	(4.6)			
01/03	1	32.8	-							29	7.2	(5.2)			
01	2	9.0	(5.7)							65	5.9	(4.1)	6	25.3	(17.5)
01/04	8	22.0	(9.8)	1	2.5	-				44	6.6	(4.0)	4	27.5	(7.8)
04/01										15	4.3	(3.7)	1	19.7	-
04	7	34.2	(13.1)				2	18.3	(5.1)	27	9.6	(6.3)	1	20.5	-
04/05	1	32.8	-							4	6.8	(3.6)			

Site	Pl			Py			Rj			Sxw		
Series	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
03							1	6.3	-			
03/01	2	12.5	(2.0)				2	5.3	(4.3)			
01/03	2	10.5	(3.8)									
01	35	22.3	(12.1)							1	3.5	-
01/04	14	20.8	(11.4)	1	14.5	-				6	4.0	(3.0)
04/01										4	16.3	(11.3)
04	7	26.6	(7.3)							4	6.2	(1.7)
04/05	1	10.0	-									

* **n** = number of sampled trees; **SD** = standard deviation.

When the data are summarized by basal area class (Tables 13 and 14), some trends appear. Douglas-fir, in particular, shows a decrease in average height growth with increasing residual basal area for both randomly selected and "best" regeneration. Western larch and lodgepole pine may show a similar pattern, although each occurs in only two classes. Interior spruce appears to have increasing height growth with increasing residual basal area.

Table 13. Average growth (cm/y) of randomly selected regeneration by species and BA class.

BA	At			Bl			Ep			Fd			Lw		
Class	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
1	8	23.2	(15.5)				2	18.3	(5.1)	49	8.4	(5.7)	9	21.7	(12.9)
2	4	20.0	(9.4)							70	4.9	(2.9)	2	13.7	(9.7)
3	2	35.8	(7.4)							25	4.7	(3.8)			
4	1	32.8	-	1	2.5	-				14	4.1	(2.8)			

BA	Pl			Py			Rj			Sxw		
Class	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
1	41	21.0	(9.6)	2	13.9	(0.9)				4	5.4	(2.7)
2	9	11.3	(5.6)				3	5.6	(3.1)	4	6.3	(2.1)
3										6	11.1	(11.5)
4												

* **class 1**: 0-9.95 m^2/ha; **class 2:** 10-19.95 m^2/ha; **class 3:** 20-29.95 m^2/ha; **class 4:** >30 m^2/ha.
* **n** = number of sampled trees; **SD** = standard deviation.

Table 14. Average growth (cm/y) of "best" regeneration by species and BA class.

BA	At			Bl			Ep			Fd			Lw		
Class	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
1	9	27.3	(17.3)				2	18.3	(5.1)	67	9.9	(5.7)	10	27.5	(12.4)
2	6	21.2	(6.3)							103	5.7	(3.5)	2	13.7	(9.7)
3	3	31.3	(8.6)							38	5.2	(3.7)			
4	1	32.8	-	1	2.5	-				20	3.9	(2.6)			

BA	Pl			Py			Rj			Sxw		
Class	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
1	53	22.7	(11.6)	1	14.5	-				3	6.2	(2.6)
2	8	13.6	(5.1)				3	5.6	(3.1)	3	6.8	(2.3)
3										9	8.7	(10.0)
4												

* **class 1**: 0-9.95 m^2/ha; **class 2:** 10-19.95 m^2/ha; **class 3:** 20-29.95 m^2/ha; **class 4:** >30 m^2/ha.
* **n** = number of sampled trees; **SD** = standard deviation.

Planned Analyses

Calibration of the small tree height growth model is underway, and will follow work done by Lencar and Marshall (2000). Calibration of the regeneration establishment component of Prognosis^{BC} has proven difficult in other areas of the Province (e.g. Boisvenue 1999), primarily due to a shortage of representative data. While a large number of Douglas-fir regeneration stems were sampled, other species were either rare or failed to be found across the desired range. Therefore, imputation methods under development by Hassani *et al.* (2002) will be used to predict regeneration for the Invermere IDFdm2.

Extension Activities

November Collaborators Meeting

Katrina Froese and Peter Marshall from the University of British Columbia flew to Invermere, BC to present the preliminary results of summer field work (described in the September, 15th report submitted to FRBC), plus some preliminary data analysis. Present at the meeting were: Barry Snowdon (BC Ministry of Forests, Victoria), representatives from the Invermere District Ministry of Forests, and several interested parties from both industry and consulting.

The meeting provided relevant feedback on the interests within the District, which will be incorporated into further analyses of the data. For example, stakeholders had a particular interest in confirming the effect of residual stand basal area on Douglas-fir height growth, which has been informally recognized in the District but not measured quantitatively.

Web Site

A web site summarizing the work at the University of British Columbia was initially released on January 31, 2002. Some revisions were implemented on March 8, 2002. The web site contains preliminary summaries of work done at UBC by Faculty, research associates, and graduate students on the Prognosis^{BC} model. There is also a list of extension products (reports, presentations, posters, and theses), including links to some products available online. Future plans for the site include providing more reports and detailed results online, plus periodic progress updates. The website is available at http://www.forestry.ubc.ca/prognosis

Poster Presentations

A poster, entitled "Prognosis^{BC} Modelling at the University of British Columbia", was presented at the Second FVS Conference, Fort Collins, Colorado, February 12-14, 2002. This poster was also presented at the University of British Columbia Forestry Research Evening, March 5, 2002. The poster summarizes the work done by UBC Faculty, research assistants and graduate students on the PrognosisBC model. The poster can be downloaded or viewed online at
http://www.forestry.ubc.ca/prognosis/documents/poster.jpg

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Appendix A. Determination of Advance Versus Subsequent Regeneration

For all components of the study, the ability to determine which regeneration existed prior to harvesting ("advance") and which developed following harvesting ("subsequent") was crucial. Ferguson and Carlson (1993) defined regeneration as seedlings 3 years old or older at the time of disturbance. Since the date of harvesting was known, any trees older than [2001 minus date of harvest plus 2] could be considered advance regeneration.

Generally, for determinate, shade intolerant species, estimating age could be done by simply counting whorls on the stem. However, for indeterminate, or more suppressed shade tolerant species, estimation of age could be more difficult. Where counting of whorls was problematic, destructive sampling was required to differentiate between advance and subsequent regeneration. The following measurement method was used to make the distinction, with the least amount of destructive sampling:

1. An "average" class four tree was destructively sampled.
2. If it was determined to be advance, and all class four trees appeared to be of similar form, it was assumed that all class four trees were advance.
3. If it was determined to be subsequent, and all class four trees appeared to be of a similar form, it was assumed that all class four trees were subsequent. In addition, if all lower class trees appeared to be of similar form, it was assumed that they, too were subsequent, and destructive sampling was ended.
4. If, in either case, class four trees were not of the same form (some appeared to be suppressed while others appeared to be open grown), one tree was sampled from each form class, and type was assigned (advance vs. subsequent) based upon the results.
5. Where not all class four trees were determined to be subsequent, the four steps were repeated, substituting class three trees. If all class three trees were determined to be subsequent, it was assumed that all lower class trees are also subsequent, and destructive sampling was stopped. If not, the steps were repeated for class two, then class one, trees if necessary.