APPENDIX B
Range of Variability

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Appendix B – Range of Variability

Introduction

The Forest Service is mandated by law and regulation to sustain the productivity of the land and the diversity of plant and animal communities (Multiple-Use Sustained-Yield Act of 1960; National Forest Management Act of 1976; National Forest System Land Management Planning 2005 Final Rule). To fulfill this mandate it's necessary to have some reference for understanding the potential productivity of the land, the natural diversity of the relevant ecosystems, and what processes sustain this productivity and diversity.

In the last 15 years, ecologists have increasingly relied upon reconstructions of historical ecosystem structures and processes to gain ecological understanding. These historical reconstructions are not meant to be a blueprint for future management, but rather to serve as reference conditions for understanding potential productivity, the range of natural diversity, and how various processes might affect that productivity and diversity. These historical references have been variously called the "range of natural variation" (Landres and others 1999); "natural variability" (Allen and others 2002; Kuuluvainen 2002; Landres and others 1999); "range of natural variability" (Landres and others 1999); "natural range of variation" (Hessburg and others 1999); "historical variability" (Wimberly and others 2000; Parsons and others 1999; Millar and Woolfenden 1999); and "historic range of variability" (Dillon 2005; Meyer 2005; Nonaka 2005; Brown and others 2004; Tinkler and others 2003; Veblen 2003; Reynolds 2003). There are slight differences in emphasis among these various terms, but they are all very similar in utilizing the concept of historical/natural conditions and processes as a reference for understanding ecosystem potential. There is also similarity in recognizing that these reference conditions involve some range. Historical range of variability is probably the most commonly used of these terms.

The January 2006 Forest Service Land Management Planning Handbook (FSH 1909.12, Chapter 40: 43.1) states that the primary approach to evaluate ecosystem diversity involves:

a. Identifying selected ecosystem characteristics.
b. Assessing their natural variation under historic disturbance regimes.
c. Comparing that to existing and projected future conditions.

The KIPZ has followed this process in developing its Historic Range of Variability (HRV). The Technical Report for the Analysis of the Management Situation for the KIPZ Forest Plan Revisions (March 2003) contained preliminary information on HRV for the planning zone. This report defined the Historic Range of Variability as the range of variation in spatial, structural, compositional, and temporal characteristics of ecosystem elements as affected by minor climatic fluctuations and disturbances. This range is measured using a reference period prior to intensive resource use and management. For the KIPZ, this period is considered to be approximately 2500 years ago up until 1880 (Chatters and Leavell 1994). The HRV is the baseline for comparison with current conditions to assess the degree of past change.

To complete the HRV and analyze current conditions, the KIPZ chose the following three ecosystem characteristics to quantify and describe:

1. Composition (Dominance type or species composition)
2. Structure (Size class)
3. Landscape pattern (Fragmentation)

Historic ranges for dominance type and size class were developed both forest-wide and by biophysical (ecological) setting. Landscape pattern was assessed by geographic area and forestwide.

Biophysical Setting

Existing and historic conditions and vegetation response to disturbance vary by ecological or biophysical setting. Each biophysical setting has characteristic potential natural communities, soils, hydrologic function, landform and topography, climate, air quality, and natural processes (nutrient and biomass cycling, succession, productivity, and fire regimes). Each setting also includes moisture and temperature gradient, resulting in growing conditions that are more similar within than between each setting. The KIPZ used three broad biophysical settings to describe these historic and current conditions:

- Warm/Dry – this setting includes the warmest and driest forest sites that support forest vegetation, usually at low elevations or mid-elevations on southerly aspects.

- Warm/Moist – this setting includes moist forest sites, usually low to mid-elevation, and includes stream bottoms and adjacent benches and toe slopes. This setting is the most productive, with favorable soil moisture and temperature regimes that favor abundant plant growth.

- Subalpine – this setting includes the moist, lower subalpine forest to the cool or cold dry sites between forest and alpine tundra. The moist end of this setting is common on northwest to east-facing slopes, riparian and poorly drained subalpine sites. The cool to cold dry sites occur at higher elevations and typically have a short growing season.

Vegetation Response Units (VRUs) were used in delineating the three biophysical settings. VRUs 1 through 3 defined the warm/dry, VRUs 4 through 6 the warm/moist, and VRUs 7 through 11 the subalpine biophysical settings. The most recent Forest VRU data was used in delineating these groups. See the KNF documentation on VRUs for further information (USDA 1999).

Sources And Methods

The HRV analysis on the zone used a wide variety of sources and methods to assess historic conditions, including:

- Information about post-glacial (last 11,00 years -- Holocene Era) climate and vegetation changes to set context for more recent conditions;
- Narrative descriptions from the early expeditions (Stevens Expedition during 1853-55 and Mullan Road Journals for 1859-61);
- Data, maps, and narrative descriptions from the 1890's contained in government surveys done in conjunction with the establishment of the Forest Reserves (Leiberg's reports);
- Data, maps, and narrative descriptions from numerous Timber and/or Forest Management Plans done on most proclaimed National Forests on approximately a decadal basis from 1910's through the 1960's;
- 1930's reports on forest conditions by county – IPNF only;
- John Losensky's 1993 report: Historical Vegetation in Region 1 by Climatic Section;

- Data from various Region 1 reports on timber conditions on National Forests during the first half of the 20th century;
- Information on fire return intervals from fire history investigations in these ecosystems;
- Historical accounts of the 1910 and other fires;
- Maps of large fires dating from approximately 1880s through the 1970s;
- Extensive sets of aerial photos from the 1930s – IPNF only;
- Spatial and numerical anlaysis of 1930's/1940's maps on six townships selected to portray the diversity of the KNF landscape – KNF only;
- Modeling results using the VDDT Model done as part of information development for the Interior Columbia River Basin Assessment (this transition model predicts vegetation condition over time using information about successional and disturbance processes) – IPNF only;
- Historical and vegetation change information from the late 1990's Interior Columbia River Basin Assessment.
- Change information from the 1998 Forest Service, Northern Region Overview
- Pollen, sediment, and charcoal analysis (Chatters and Leavell 1994)
- Negative exponential model for age classes

A variety of historic data and information sources was assessed and compared to avoid omissions and biases that may be inherent in any one source. Trends through time from one data source to another were examined to uncover any information that may be in contradiction to the preponderance of evidence. Information in both narratives and historical forest inventories was also compared to objective evidence such as historic landscape scale photos, historical records and maps of major forest fires, and various fire history studies. Findings from the Interior Columbia River Basin Assessment, the US Forest Service Northern Region Overview, and model (VDDT and negative exponential model) results were also included in the analysis.

Both Forests have worked on developing HRV over the past several years. Development of HRV has been an iterative process, involving teams of specialists from the districts and Supervisor's Offices, including silviculturists, ecologists, timber managers, wildlife biologists, and fire managers with extensive field knowledge. These specialists reviewed the historic and current information to develop historic conditions for their study area (on the IPNF, the geographic areas and on the KNF, the planning subunit or river subbasin). In addition, other studies were recently completed (i.e., the Interior Columbia River Basin Assessment) that provide HRV descriptions for the forests, as well as a comparison to existing conditions.

In addition, two parametric fire history models (the negative exponential and the Weibull models) were used to develop theoretical age class distributions. These models were tailored for Forest fire regimes and diversity. These outputs were reviewed and adjusted based on data from existing stands (analysis of age class and structure) and an understanding of historic disturbance effects.

Composition And Structure

The KIPZ used dominance type and size class to describe vegetation composition and structure. Historic records were reviewed and compared to existing data to develop classes that could be assessed. The historic and existing data had to be crosswalked to a set of common terms and classes for use in the analysis.

Dominance type classes were defined by reviewing historic and current records to determine which species were/are relatively abundant. The following dominance types by biophysical group were used in defining HRV:

- Warm/Dry: Ponderosa pine, Douglas-fir, lodgepole pine, and western larch
- Warm/Moist: Douglas-fir, western larch, grand fir/cedar/western hemlock mix (termed grand fir mix), and white pine.
- Subalpine: Lodgepole pine, western (and subalpine) larch, white pine, and spruce-fir mix

Size class was used as a proxy for describing vegetation structure. Size class can be crosswalked to stand age and structure. Size classes were chosen based on historic and existing data classifications, the ability to crosswalk the data to common classes, and information needed for wildlife habitat modeling. The following size classes were used for each biophysical group and forestwide:

- Seedling/sapling (0-5 inch DBH)
- Small (5-10 inch DBH)
- Medium (10-15 inch DBH)
- Large (>15 inch DBH)

Although mostly within the large size class, old growth was tracked as a separate measure and class.

For comparing historic and existing data and for modeling purposes, age classes were developed for each of the size classes. On the IPNF, age is generally correlated to size class as follows:

Seedling/sapling = 0 – 35 years
Small = 35 – 60 years
Medium = 60 – 100 years
Large = 100 plus years

On the KNF, age is generally correlated to size class as follows:

Seedling/sapling = 0 – 40 years
Small = 40 – 70 years
Medium = 70 – 100 years
Large = 100 plus years

The HRV analysis resulted in a mean value for each dominance type and size class by individual VRU. A weighted mean average was calculated for each biophysical group, based on the amount of each VRU within a group. See Tables B-1 through B-4 for the mean HRV value by biophysical class for dominance type and size class by forest.

Table B-1 HRV mean value for dominance type on the IPNF

Dominance Type	Warm/Dry (VRUs 1-3) %	Warm/Moist (VRUs 4-6) %	Subalpine (VRUs 7-11) %
PP	48		
DF	39	21	
LP	5		17
WL	8	19	12
GF/C/WHmix		15	
WP		45	10
Sfmix			61

Table B-2 HRV mean value for dominance type on the KNF

Dominance Type	Warm/Dry (VRUs 1-3) %	Warm/Moist (VRUs 4-6) %	Subalpine (VRUs 7-11) %
PP	32		
DF	8	11	
LP	11		37
WL	49	55	19
GF/C/WHmix		22	
WP		12	5
Sfmix			39

Table B-3 HRV mean value for size class on the IPNF

Size Class	Warm/Dry (VRUs 1-3) %	Warm/Moist (VRUs 4-6) %	Subalpine (VRUs 7-11) %
seed/sap	21	22	21
small	14	12	15
medium	15	20	20
large	49	46	44

Table B-4 HRV mean value for size class on the KNF

Size Class	Warm/Dry (VRUs 1-3) %	Warm/Moist (VRUs 4-6) %	Subalpine (VRUs 7-11) %
seed/sap	20	23	25
small	13	15	15
medium	11	13	12
large	56	49	48

To complete the HRV analysis for dominance type and size class, three ranges were built around the mean, based on percentages. The three ranges were labeled HRV Class A, Class B, and Class C. The HRV Class A was calculated as plus or minus 33% of the mean. The HRV Class B was calculated as plus or minus 34% - 67% of the mean. The HRV Class C was calculated as plus or minus more than 67% of the mean. These calculated ranges (0-33%, 34-67%, and >67%) are consistent with ranges used in developing fire regime condition class, which define departure from natural fire regime of intensity and frequency (Hann and Bunnell 2001, Hardy et al. 2001, and Schmidt et al. 2001).

Tables B-5 and B-6 display the ranges for dominance by HRV Classes A and B for each Forest. Tables B-7 and B-8 display the ranges for size class by HRV Classes A and B for each Forest. HRV Class C is the range outside Class B, from zero to the Class B lower limit and from the Class B upper limit to 100.

Table B-5 HRV Class for Dominance Type for the IPNF

HRV Class A								
	VRUs 1-3		VRUs 4-6		VRUs 7-11		Forestwide	
	Warm/Dry		Warm/Moist		Subalpine		FS Lands	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
PP	32	64					5	10

HRV Class A								
DF	26	52	14	28			12	25
LP	3	7			11	23	3	6
WL	5	11	13	25	8	16	10	21
GF/C/WHmix			10	20			6	12
WP			30	60	7	13	20	39
Sfmix					41	81	10	20
HRV Class B								
	VRUs 1-3		VRUs 4-6		VRUs 7-11		Forestwide	
	Warm/Dry		Warm/Moist		Subalpine		FS Lands	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
PP	16	80					2	12
DF	13	65	7	35			6	31
LP	2	8			6	28	2	8
WL	3	13	6	32	4	20	5	26
GF/C/WHmix			5	25			3	15
WP			15	75	3	17	10	50
Sfmix					20	102	5	25

Table B-6 HRV Class for Dominance Type for the KNF

HRV Class A								
	VRUs 1-3		**VRUs 4-6**		**VRUs 7-11**		**Forestwide**	
	Warm/Dry		**Warm/Moist**		**Subalpine**		**FS Lands**	
	Lower Limit	**Upper Limit**	**Lower Limit**	**Upper Limit**	**Lower Limit**	**Upper Limit**	**Lower Limit**	**Upper Limit**
PP	21	43					5	9
DF	5	11	7	15			4	8
LP	7	15			25	49	12	23
WL	33	65	37	73	13	25	26	52
GF/C/WHmix			15	29			5	11
WP			8	16	3	7	4	9
Sfmix					26	52	11	21
HRV Class B								
	VRUs 1-3		**VRUs 4-6**		**VRUs 7-11**		**Forestwide**	
	Warm/Dry		**Warm/Moist**		**Subalpine**		**FS Lands**	
	Lower Limit	**Upper Limit**	**Lower Limit**	**Upper Limit**	**Lower Limit**	**Upper Limit**	**Lower Limit**	**Upper Limit**
PP	11	53					2	12
DF	3	13	4	18			2	10
LP	4	18			12	62	6	29
WL	16	82	18	92	6	32	13	65
GF/C/WHmix			7	37			3	14
WP			4	20	2	8	2	11
Sfmix					13	65	5	27

Table B-7 HRV Class for Size for the IPNF

HRV Class A								
	VRUs 1-3		VRUs 4-6		VRUs 7-11		Forest-wide	
	Warm/Dry		Warm/Moist		Subalpine		FS Lands	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
seed/sap	14	28	15	29	14	28	14	29
small	9	19	8	16	10	20	9	17
medium	10	20	13	27	13	27	13	26
large	33	65	31	61	29	59	31	61
HRV Class B								
	VRUs 1-3		VRUs 4-6		VRUs 7-11		Forest-wide	
	Warm/Dry		Warm/Moist		Subalpine		FS Lands	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
seed/sap	7	35	7	37	7	35	7	36
small	5	23	4	20	5	25	4	22
medium	5	25	7	33	7	33	6	32
large	16	82	15	77	15	73	15	77

Table B-8 HRV Class for Size for the KNF

HRV Class A								
	VRUs 1-3		VRUs 4-6		VRUs 7-11		Forest-wide	
	Warm/Dry		Warm/Moist		Subalpine		FS Lands	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
seed/sap	13	27	15	31	17	33	16	31
small	9	17	10	20	10	20	10	19
medium	7	15	9	17	8	16	8	16
large	38	74	33	65	32	64	34	67
HRV Class B								
	VRUs 1-3		VRUs 4-6		VRUs 7-11		Forest-wide	
	Warm/Dry		Warm/Moist		Subalpine		FS Lands	
	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit	Lower Limit	Upper Limit
seed/sap	7	33	8	38	8	42	8	39
small	4	22	5	25	5	25	5	24
medium	4	18	4	22	4	20	4	20
large	18	94	16	82	16	80	17	84

Because of it's social and ecological significance and because it does not completely fit within the size classes defined, old growth was tracked separate from size class. National forests in the Forest Service Northern Region use the old growth definitions contained in *Old Growth Forest Types of the Northern Region* by Green and others (1992, errata corrected 2005). The old growth

definitions are specific to forest type / habitat type groups, and are defined by a minimum number of trees of a minimum age and diameter, in stands with a minimum density. The most common KIPZ old growth types require 10+ trees per acre that are 150 years+ in age and 21”+ in diameter, in stands of at least 80 square feet of basal area.

Most historic forest data is not detailed enough to apply the Green and others (1992/2005) old growth definitions. Many of the historic inventories tallied forests by dominant age classes. To determine HRV, the 150+ year old age class from historic inventories was used as a starting point, with an adjustment for younger stands that had a remaining older cohort. KIPZ forests commonly experienced disturbances that were not always entirely stand replacing (low and mixed severity fires, partial windthrow, insect attacks that killed many, but not all the mature trees, etc.). In historic inventories, some stands (which experienced mixed severity disturbance) were likely assigned a young age based on the majority of live trees in the main canopy, even though the stand retained 10 or more older, bigger residual trees that by today’s standards would qualify them as old growth. Hessburg and others (1999), and Weisberg (2004) reached similar conclusions about the importance of residual large, old trees in younger stands as a result of non-stand-replacing fire. As explained above, two parametric fire history models (the negative exponential and the Weibull models) were used to develop theoretical age class distributions, based on Forest fire regimes and diversity. Outputs from these models were reviewed and adjusted based on an analysis of existing age and structure of old growth stands and historic data.

Table B-9 displays the mean HRV value by biophysical class for old growth for each Forest. Tables B-10 and B-11 display the ranges for old growth by HRV Classes A and B for each Forest. HRV Class C is the range outside Class B, from zero to the Class B lower limit and from the Class B upper limit to 100.

Table B-9 HRV mean value for old growth on the KIPZ

Forest	Warm/Dry (VRUs 1-3) %	Warm/Moist (VRUs 4-6) %	Subalpine (VRUs 7-11) %
IPNF	31	26	25
KNF	41	31	32

Table B-10 HRV Class for Old Growth for the IPNF

Old Growth								
	VRUs 1-3		VRUs 4-6		VRUs 7-11		Forest-wide	
	Warm/Dry		Warm/Moist		Subalpine		FS Lands	
	Min	Max	Min	Max	Min	Max	Min	Max
HRV Class A	21	41	17	35	17	33	18	35
HRV Class B	10	52	9	43	8	42	9	44

Table B-11 HRV Class for Old Growth for the KNF

Old Growth								
	VRUs 1-3		VRUs 4-6		VRUs 7-11		Forest-wide	
	Warm/Dry		Warm/Moist		Subalpine		FS Lands	
	Min	Max	Min	Max	Min	Max	Min	Max
HRV Class A	27	55	21	41	21	43	23	45
HRV Class B	14	68	10	52	11	53	11	56

It's important to recognize the limitations of using historic forest inventories to compare historic to current forest conditions. To be meaningful, raw tree data is always summarized into forest categories (such as forest cover type, forest size classes, and forest age classes). Over time, there may be changes both in category definitions, and in methodologies for gathering data and computing category membership. It is necessary to research changes in inventory definitions and methods over time, and important to build crosswalks so that common terms are used across time periods. However, crosswalks are never perfect, and this inevitably results in some noise in the data. Further, hard data across inventory periods may not be available for all items of interest, and to address these items it is necessary to use informed inference from related information.

Because of the inevitable noise in comparing current and historic forest conditions, caution is necessary in how this information is used. We cannot be sure that small differences between current and historic vegetation categories are real, rather than the result of the inevitable noise. On the other hand, even in the face of some noise we can be more confident about large changes from historic to current that are found in some forest categories. We strengthen confidence about findings of changes from historic to current forest conditions when similar changes are found from different studies, or through different methods of historic analysis. The most robust finding about changes from historic conditions occurs when the magnitude of the change is large, and a similar trend is found through a variety of different analysis methods, and through several different studies.

Landscape Pattern

To understand how ecosystems function, among other things, it's important to understand not just how much there is of various vegetative structures, but to also understand the patterns of how vegetation structures are arranged on the landscape. Landscape pattern affects numerous ecological process, including: watershed functioning; wildlife habitat and dispersal; plant habitat and dispersal; disturbance (fire, insects, pathogens) risk, spread and size; ecosystem response to disturbance; and human esthetic values.

Both Forests have reviewed historic and existing landscape patterns (IPNF GA assessments; KNF subbasin assessment and various EAWS). A variety of methods and sources were used in reviewing landscape pattern. Aerial photos and inventory maps from the mid-1930s were compared with current photos and trends in landscape pattern changes noted. Historic data on landscape pattern is very minimal, making it difficult to develop a historic range of variability for pattern. Although the mid-1930s was used as a comparison for landscape pattern, it's important to note this is just one point in time and the landscape in the 1930s was heavily influenced by the extensive fires of 1910. However, some inference can be made regarding change from historic conditions.

To quantitatively assess the existing landscape pattern, the FRAGSTATS model (McGarigal and Marks 1995) was used. FRAGSTATS is a spatial pattern analysis program for mapped data. The program quantifies the areal extent and spatial configuration of patches within a landscape.

To assess fragmentation on the KIPZ, size classes were grouped into patch classes. The VMP coverage was used for the size class. Shrub and grass/forbs were updated to seedling/sapling for plantations (0-40 years old) and high severity fires. Size class was also updated to very large size class from the forests' old growth inventories. See Appendix G for more information on the existing vegetation coverage.

Table B-12 displays the classification used in completing the FRAGSTATS analysis. Two sets of runs were made with different classifications of size class:

Table B-12 Classifications for FRAGSTATS Analysis

Classification 1	
Size Class from Updated VMAP	Patch Class for Analysis
Seedling/sapling, grass/forbs, shrubs, sparsely vegetated (0-5" dbh)	Open
Small (5-10" dbh)	Small
Medium, Large, Very Large (10+")	Medlarge
Water	Background

Classification 2	
Size Class from Updated VMAP	Patch Class for Analysis
Very Large (20+")	Verylarge
All other size classes and non-tree vegetation	Other
Water	Background

Resulting polygons were kept to a minimum size of 5 acres. The polygon coverage was converted to grid using a 30 meter cell size. Runs were made for each GA and for each Forest. The following indices from FRAGSTATS were used to assess fragmentation:

1. Percent of the landscape in a particular patch class (class metric – PLAND) equals the sum of the areas (m2) of all patches of the corresponding patch type, divided by total landscape area (m2), multiplied by 100 (to convert to a percentage); in other words, PLAND equals the percentage the landscape comprised of the corresponding patch type. Note, total landscape area (A) includes any internal background present.

2. Area weighted mean patch area (class metric - AREA_AM) – equals the sum, across all patches of the corresponding patch type, of the corresponding patch metric value multiplied by the proportional abundance of the patch.

3. Patch size standard deviation (class metric - AREA_SD) – equals the square root of the sum of the squared deviations of each patch metric value from the mean metric value of the corresponding patch type, divided by the number of patches of the same type; that is, the root mean squared error (deviation from the mean) in the corresponding patch metric. Note: this is the population standard deviation, not the sample standard deviation.

4. Contrast-weighted edge density (class and landscape metrics - CWED) – Use only with Classification 1. It is the ratio of edge to patch area for each patch class, with each segment of edge weighted based on how much contrast there is in that edge type. The following weights were used:
   Open to small = 0.5
   Open to medlarge = 1.0
   Small to medlarge = 0.5

5. Edge density (class and landscape metrics - ED) – Use only with Classification 2. It is the sum of the lengths (m) of all edge segments involving the corresponding patch type, divided by the total landscape area (m2), multiplied by 10,000 (to convert to hectares).

6. Landscape shape index (class and landscape metrics - LSI) –compares the amount of edge per unit area for a given patch class to the amount of edge per unit area that would be present if that patch class was one large circular patch. Shape index becomes larger as patches become more irregular in shape, are internally fragmented, or become long skinny strips rather than wide polygons.

7. Total core area (class and landscape metrics – TCA) – the amount of core area present within the class or landscape.

8. Core area percentage of landscape (class metric - CPLAND) – the percent of the entire landscape that's in core area (interior habitat) of a particular patch class based on a 90m edge width.

9. Area weighted mean of core areas (landscape metric – CORE_AM)

10. Area weighted mean Euclidean nearest-neighbor (class metric – ENN_AM) – the sum of the distance to the nearest patch of the same type, based on nearest edge-to-edge distance, for each patch in the landscape with a neighbor, divided by the number of patches with a neighbor multiplied by the proportional abundance of the patch type.

11. Euclidean nearest-neighbor coefficient of variation (class metric – ENN_CV) – the standard deviation in nearest neighbor distances divided by the mean nearest neighbor distance multiplied by 100.

12. Area weighted mean fractal dimension (class metric - FRAC_AM) – two times the logarithm of patch perimeter (m) divided by the logarithm of patch area (m2); the perimeter is adjusted to correct for the raster bias in perimeter divided by the number of patches and multiplied by the proportional abundance of the patch type.

13. Interspersion and juxtaposition index (class and landscape metrics - IJI) – the observed interspersion over the maximum possible interspersion for the given number of patch types.

14. Clumpiness index (class and landscape metric - CLUMPY) –equals the proportional deviation of the proportion of like adjacencies involving the corresponding class from that expected under a spatially random distribution.

Results of the fragmentation analysis indicate the landscape pattern on the KIPZ in some areas is more fragmented than what probably occurred historically. For information on the fragmentation analysis results, see the wildlife section in Chapter 2.

Reference Periods And Climatic Variability

Geology and paleoecology research indicate the earth's climate and vegetation have varied throughout the history of the planet. Information about this variation is necessary to set context for consideration of HRV.

Although climate change is nothing new, there tend to be long periods in the earth's history when climate is similar enough that the resulting vegetation and vegetation disturbances processes are operating within the same general realm. To intelligently discuss the historical range of variability, it's necessary to determine what recent time period encompassed climatic conditions and resultant vegetation similar enough to current condition to be relevant for HRV discussions.

The last glacial period in the northern hemisphere ended approximately 11,000 years ago. For thousands of years prior to that time, the northern one-third of the IPNF and northern one-half of the KNF was covered by the continental ice sheet. The higher elevations throughout the KIPZ were covered in alpine glaciers. Over the rest of the landscape, growing conditions and vegetation were very different from what occurs today.

Since the end of the last glaciation in this region, there have been at least three to four periods of substantially different climate and resultant vegetation (Mack and others 1983; Mehringer 1985; Whitlock 1992). In the inland northwest, following several periods of change after the end of the last glaciation, the period between approximately 7,000 and 4,000 years ago was significantly warmer and drier than 20th century conditions, with more xeric vegetation occupying an expanded range. After about 4,000 years before present, inland northwest climate began to cool and become wetter. At some time, between approximately 4,000 and 2,000 years ago, the local climate and vegetation began to be substantially similar enough to current conditions that it makes sense to consider in assessing the range of historic variability. The plant and animal communities that the first Euro-American explorers found here, was what had developed in response to climate during this most recent time period.

At a finer time scale, the few hundred years before Euro-American settlement were a cooler sub-set of conditions within the broad climatic regime of the last 2,000 years. This cooler period is often referred to as the "Little Ice Age". The time of Euro-American settlement approximates the end of the "Little Ice Age", and introduces some questions about what proportion of the changes in disturbance regimes that have been seen in the last century are due to human actions, and what proportion are due to some change in the climate.

Some scientists see evidence of current and future global warming. However, even assuming global warming, there are several possible scenarios about how this might play out in the northern Rocky Mountains in terms of effects on moisture regimes, and seasonality of possible temperature and moisture regime changes. Different models produce different results for the Northern Rocky Mountains.

EXISTING VEGETATION COMPOSITION AND SIZE

The most recent forest-wide FIA inventory was used as the source for forest dominance type and size class by biophysical group and forest-wide. The FIA data used for forest planning was collected from 1993 to 1995 for the KNF and 1999 to 2002 for the IPNF. Data collected on the KNF was summarized and documented in the report *Forest Resources of the Kootenai National Forest* (Wilson and Miles, 2000). The use of FIA data in broad-scale assessments, such as forest planning, has been documented as a valid and reliable data source (Czaplewski 2004).

A summary database application developed by the regional office (R1 FIA Summary Database) was used in querying the FIA and associated data. Queries were made by biophysical, or vegetation response unit (VRU) group. Only primary sample units (PSUs) without fire or timber harvest since inventory were included in the queries for size class and dominance.

For size class, queries retrieved data for forest, PSU (Primary Sample Unit) ID, Plot ID, oldgrowth, size class, and VRU. The size class field is the basal area weighted diameter calculated as defined and shown in the National Technical Guide as the following classes: 0.1-4.9" DBH, 5.0 – 9.9" DBH, 10.0 – 14.9" DBH, 15.0 – 19.9" DBH, 20.0 – 24.9" DBH, and 25.0"+. Final queries for size class were made on September 2, 2005.

For dominance type, queries retrieved data for forest, PSU ID, Plot ID, dominance type, and VRU. The dominance type field was defined using the R1 Vegetation Council Algorithm for Stand Classification regarding dominance[1]. Final queries for dominance type were made on July 6, 2005.

To determine the number of plots within a VRU group with disturbance since inventory, queries were also made of all the PSU ID and Plot ID by VRU for all PSUs (including those with harvest or fire). All query results were loaded into an access database on the forest, where the FIA data was converted to the size classes and dominance types found within the HRV analysis. For dominance type, VRU was used to crosswalk the FIA dominance type to the dominance type used in HRV by VRU group. Summary queries were run to total the number of plots by VRU group. Results were loaded into spreadsheets where final proportions were calculated. Plots with disturbance (fire or harvest) since inventory were included as part of the total, but tracked separately.

Summaries were generated of proportions by size class or dominance type by biophysical group and forest-wide, based on the number of subplots within a stratum. A 90 percent confidence was generated around each proportion using a spreadsheet designed for calculating confidence intervals. Tables B-13 and B-14 display proportions and confidence intervals by size class. Tables B-15 and B-16 display proportions and confidence intervals by dominance type for each Forest.

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[1] For plots with 20 square feet or more of basal area, dominance is based off of basal area. If a plot has less than 20 square feet of basal area but at least 100 trees per acre then dominance is based on trees per acre. If neither basal area nor trees per acre criteria is met, a dominance call is not made and will be labeled as 'none' in the database. The proportion of the dominance attribute, either basal are or trees per acre, is then calculated for each species occurring on the plot.

Single species – species make up at least 60% of the dominance attribute.

Two species – two species comprise at least 80% of the dominance attribute with each individual species contributing more than 20% of the total.

Three species – three species comprise at least 80% of the dominance attribute with each individual species contributing more than 20% of the total.

Mix – no single, two, or three species call can be made. Type of mix, either intolerant or tolerant, is determined by what species combination has plurality of dominance attribute.

TGCH: if grand-fir (ABGR), western redcedar (THPL), and/or western hemlock (TSHE) comprise the plurality of the dominance attribute.

TASH: if majority of the dominance attribute is in subalpine fir (ABLA), Engelmann spruce, and/or mountain hemlock (TSME).

IMXS: if majority of the dominance attribute is from a combination of any other species.

Table B-13 IPNF Proportion of FIA Subplots by Size Class and Old Growth

	Biophysical Group															
	Warm/Dry				Warm/Moist				Subalpine				Forest-wide			
			90% Conf. Int.				90% Conf. Int.				90% Conf. Int.				90% Conf. Int.	
Size class	**subplots**	**%**	**low**	**high**	**subplots**	**%**	**low**	**high**	**subplots**	**%**	**low**	**high**	**subplots**	**%**	**low**	**high**
seed/sap (0-5")	15	6%	4%	9%	72	8%	7%	10%	29	7%	5%	9%	119	8%	7%	9%
small (5-10")	54	23%	19%	28%	167	19%	16%	21%	107	26%	23%	30%	338	22%	20%	23%
medium (10-15")	59	25%	21%	30%	279	31%	29%	34%	141	35%	31%	39%	485	31%	27%	30%
large (15"+)	76	32%	27%	38%	307	34%	32%	37%	104	26%	22%	29%	494	32%	30%	34%
none 1/	26	11%			44	5%			19	5%			92	6%		
disturbance 2/	4	2%			28	3%			4	1%			36	2%		
Total	234	100%			897	100 %			404	100 %			1564	100 %		
All Plots without disturb.	208				853				385				1472			
Total w/o fire/harv	230				869				400				1528			

1/ "none" is for plots with <20 sqft BA or <100 TPA
2/ "disturbance" is plots that have had fire (any intensity level) or harvest (any type) since the plot was taken

old growth	10	4%	2%	6%	91	10%	8%	12%	96	24%	20%	27%	200	13%	11%	14%

Table B-14 KNF Proportion of FIA Subplots by Size Class and Old Growth

	Biophysical Group															
	Warm/Dry				Warm/Moist				Subalpine				Forest-wide			
			90% Conf. Int.				90% Conf. Int.				90% Conf. Int.				90% Conf. Int.	
Size class	**subplots**	**%**	**low**	**high**	**subplots**	**%**	**low**	**high**	**subplots**	**%**	**low**	**high**	**subplots**	**%**	**low**	**high**
seed/sap (0-5")	80	14%	12%	16%	151	17%	15%	19%	151	17%	15%	19%	382	16%	15%	17%
small (5-10")	103	18%	15%	21%	214	24%	21%	26%	210	24%	22%	26%	527	22%	21%	24%
medium (10-15")	134	24%	21%	26%	248	27%	25%	30%	190	22%	19%	24%	572	24%	23%	26%
large (15"+)	127	22%	19%	25%	184	20%	18%	22%	136	16%	13%	18%	447	19%	18%	20%
none 1/	56	10%			35	4%			80	9%			171	7%		

disturbance 2/	70	12%			78	9%			110	13%			258	11%		
Total	570	100%			910	100%			877	100%			2357	100%		
Total w/o fire/harv	500				832				767				2099			

1/ "none" is for plots with <20 sqft BA or <100 TPA

2/ "disturbance" is plots that have had fire (any intensity level) or harvest (any type) since the plot was taken

old growth	52	9%	7%	11%	70	8%	6%	9%	94	11%	9%	12%	216	9%	7% 3/	11% 3/
3/ calculated from boot strap in R1 FIA Summary Database, rather than ci spreadsheet																

Table B-15 IPNF Proportion of FIA Subplots by Dominance Type

	Biophysical Group															
	Warm/Dry				**Warm/Moist**				**Subalpine**				**Forest-wide**			
			90% Conf. Int.				**90% Conf. Int.**				**90% Conf. Int.**				**90% Conf. Int.**	
Dominance Type	**subplots**	**%**	**low**	**high**	**subplots**	**%**	**low**	**high**	**subplots**	**%**	**low**	**high**	**subplots**	**%**	**low**	**high**
PP	24	10%	7%	14%									24	2%	1%	2%
DF	148	63%	58%	68%	244	27%	25%	30%					392	25%	23%	27%
LP	22	9%	6%	13%					64	16%	13%	19%	86	5%	5%	6%
WL	10	4%	2%	6%	132	15%	13%	17%	6	1%	0%	2%	148	9%	8%	11%
GF/C/WHmix					427	48%	45%	50%					430	27%	26%	29%
WP					22	2%	2%	3%	9	2%	1%	3%	31	2%	1%	3%
SFmix									302	75%	71%	78%	325	21%	19%	22%
None 1/	26	11%			44	5%			19	5%	3%	6%	92	6%		
Disturbance 2/	4	2%			28	3%			4	1%	0%	2%	36	2%		
Total	234	100%			897	100 %			404	100 %			1564	100 %		
Total w/o fire/harv	230				869				400				1528			

1/ "none" is for plots with <20 sqft BA or <100 TPA
2/ "disturbance" is plots that have had fire (any intensity level) or harvest (any type) since the plot was taken

Table B-16 KNF Proportion of FIA Subplots by Dominance Type

	Biophysical Group															
	Warm/Dry				**Warm/Moist**				**Subalpine**				**Forest-wide**			
			90% Conf. Int.				**90% Conf. Int.**				**90% Conf. Int.**				**90% Conf. Int.**	
Dominance Type	**subplots**	**%**	**low**	**high**	**subplots**	**%**	**low**	**high**	**subplots**	**%**	**low**	**high**	**subplots**	**%**	**low**	**high**
PP	55	10%	8%	12%									55	2%	2%	3%
DF	291	51%	48%	54%	327	36%	33%	39%					618	26%	25%	28%
LP	46	8%	6%	10%					151	17%	15%	19%	197	8%	7%	9%
WL	52	9%	7%	11%	199	22%	20%	24%	100	11%	10%	13%	351	15%	14%	16%
GF/C/WHmix					256	28%	26%	31%					256	11%	10%	12%
WP					15	2%	1%	2%	2	0%	0%	0%	17	1%	0%	1%
SFmix									434	49%	47%	52%	434	18%	17%	20%
None 1/	56	10%			35	4%			80	9%			171	7%		
Disturbance 2/	70	12%			78	9%			110	13%			258	11%		
Total	570	100%			910	100 %			877	100 %			2357	100 %		
Total w/o fire/harv	500				832				767				2099			

1/ "none" is for plots with <20 sqft BA or <100 TPA
2/ "disturbance" is plots that have had fire (any intensity level) or harvest (any type) since the plot was taken

Applying Hrv To Forest Planning

Ecological literature of the past 15 years uses the concept of a "natural range of variability" or a "historic range of variability" as a template or reference point for understanding how a fully functioning ecosystem worked in a given landscape and what range of biological diversity it included. For Forest Planning, the KIPZ developed mean historic values for forest structure and composition. Historic conditions were not static, and there was a natural range of variability. When analyzing historic data, however, it is very difficult to reliably determine what reflects the range of natural variability, and what variability in the data simply represents noise in the analysis process. Rather than make conclusions that weren't solidly grounded, ranges were developed around the means that were based on a bell-shaped curve and in keeping with recent science and literature on this depiction of variability (Hann and Bunnell 2001, Hardy et al. 2001, and Schmidt et al. 2001).

Many reviewers of the concept of HRV recognize that historical ecological data is inherently noisy and consequently recommend using a variety of approaches to understanding the historical range of variability for any given ecosystem. Some reviewers also caution against relying on a single point in time.

The KIPZ used several sources covering different points in time in developing the HRV. These sources include a wide variety of historical inventories conducted at various scales, old aerial photos, understanding of vegetation types likely to result from historical fire regimes, model results, narrative descriptions, and pollen studies. When assessing the larger classes of forest types and size classes, results were very similar between the various sources. This similarity in data supports the conclusion that the broader findings of the KIPZ historical analysis are relatively robust.

The quantitative vegetative and narrative historic information used in the HRV analysis spans the period from approximately 1850 through 1940. However, because trees are long-lived organisms, the forests of this time period should be seen as not just a single point in time, but as the net product of the previous several hundred years of climatic influences and disturbance processes. The fire history information, based on fire scars and dendrochronology, goes back to the 1500's. Over this period, some changes in fire frequencies can be identified, but the types and general patterns of fire disturbances over this time are broadly capable of producing similar vegetation patterns. Based on pollen studies, references can be made to broad climatic regime and forest species data that goes back for several thousand years. These pollen records do not produce precise fire interval data for this whole time period, or precise vegetation mixes or age classes. However, most paleoecologists have interpreted the local pollen record to infer that the broad climate regime has been substantially the same in this region for approximately 2,500, and the mix of dominant vegetation types has been approximately the same for the last 1,500 to 2,500 years.

As discussed previously, weather and climate are variable on almost every scale examined, from individual years, to decades, to centuries, to millennia. However, none of the data discussed above is inconsistent with the broad findings about HRV, based on more recent and precise quantitative historical data.

Of more concern is the fact that the area including and surrounding this national forest was historically occupied by somewhere between 5,000 and 10,000 Native Americans living a largely

hunter and gatherer lifestyle. Now, this same area is occupied by over 600,000 people, leading a much more consumption lifestyle, and is readily accessible to millions of more potential visitors. The sheer number of people and how they change the environment means that the context for current forests in the planning area is very different from what it was historically. Besides direct effects from their occupancy, certain sorts of historic disturbances (such as large stand replacing wildfires) may now be considered undesirable, and attempts to change major natural disturbance regimes has major implications for ecosystem composition, structure, and function.

In addition, there have been some biological changes that are essentially irreversible. The early 1900's introduction of the exotic tree disease, white pine blister rust, has decimated the historically most common tree species in northern Idaho, western white pine. Blister rust has also had major devastating impacts on whitebark pine in the subalpine system. This change alone produces cascading impacts throughout the KIPZ forested ecosystems. These white pine species do have a low level of natural resistance to blister rust. Between natural selection and planting of blister rust resistant seedlings that have been developed by tree improvement programs, there may be some substantial recovery of white pine and whitebark pine over the next few centuries. But, at least for the next hundred plus years, these ecosystems are likely to function somewhat differently than they did historically before the introduction of blister rust.

The above changes, plus the additional possibility of human induced global warming, all raise questions about how HRV should be used. As stated previously, the Historic Range of Variability is not used as a management objective or target. Rather, the historic range of variability is a reference to inform management decisions. So, for example, if the HRV analysis indicates that historically approximately 50% of forest dominance types were fire adapted, drought-tolerant, shade-intolerant, potentially long lived tree species, this raises questions about whether current forests increasingly dominated by high moisture demanding, fire-sensitive, shade tolerant tree species will be resistant to natural disturbance agents. Further, if the climate really is warming, it's reasonable to expect more moisture stress, and more fires. That only heightens the concern about the direction of recent shifts in forest dominance types. There is a need to restore fire adapted, drought tolerant, shade-intolerant tree species because they are most resilient in the face of expected natural disturbance regimes (especially under the pretext of global warming). The KIPZ restoration objective is based on this functional relationship – not just on the fact that current vegetation is different than historic.

As our knowledge of HRV and ability to model historic composition and structure improve, HRV will be updated for the KIPZ.

LITERATURE CITED

Allen, Craig D.; Savage, Melissa; Falk, Donald A.; Suckling, Kieran F.; Swetnam, Thomas W.; Schulke, Todd; Stacey, Peter B.; Morgan, Penelope; Hoffman, Martos; Klingel, Jon. T. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: a broad perspective. Ecological Applications. 12(5): 1418-1433.

Brown, Richard T.; Agee, James K.; Franklin, Jerry F. 2004. Forest restoration and fire; principles in the context of place. Conservation Biology. 18(4): 903-912.

Chatters, J.C. and D.M. Leavell. 1994. Smeads Bench Fen: a 1500 year history of fire and succession in the hemlock forests of the lower Clark Fork Valley, northwestern Montana. Draft form only. USDA Forest Service, Kootenai National Forest, Libby, MT. 77 pp.

Dillon 2005 – Art needs to provide citation

Czaplewski, Raymond L. 2004. *Application of Forest Inventory and Analysis (FIA) Data to Estimate the Amount of Old Growth Forest and Snag Density in the Northern Region of the National Forest System.* Not published.

Green, P.; Joy, J.; Sirucek, D.; Hann, W.; Zack, A.; Naumann, B. 1992 (errata corrected 02/2005). Old growth forest types of the Northern Region. In: R-1 SES 4/92. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region. 60p.

Hann, W.J., Bunnell, D.L. 2001. *Fire and land management planning and implementation across multiple scales*. International Journal of Wildland Fire. 10:389-403.

Hardy, C.C., Schmidt, K.M., Menakis, J.M., Samson, N.R. 2001. *Spatial data for national fire planning and fuel management*. International Journal of Wildland Fire 10:353-372.

Hessberg, Paul F.; Smith, Bradley G.; Kreiter, Scott D.; Miller, Craig A.; Salter, R.Brion; McNicoll, Cecilia H.; Hann, Wendell J. 1999. Historical and current forest and range landscapes in the interior Columbia River basin and portions of the Klamath and Great Basins. Part I: Linking vegetation patterns and landscape vulnerability to potential insect and pathogen disturbances. Gen. Tech. Rept. PNW-GTR-458. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 357 p. (Quigley, Thomas M., ed., Interior Columbia Basin Ecosystem Management Project: scientific assessment).

Kuuluvainen, Timo. 2002. Natural variability of forests as a reference for restoring and managing biological diversity in boreal Fennoscandia. Silva Fennica 36(1): 97–125.

Landres, Peter B.; Morgan, Penelope; Swanson, Frederick J. 1999. Overview of the use of natural variability concepts in managing ecological systems. Ecological Applications, 9(4): 1179-1188.

Leiberg, John B. 1897. General report on a botanical survey of the Coeur d'Alene Mountains in Idaho during the summer of 1895. Contributions from the U.S. National Herbarium, Vol. V, No. 1, Issued January 25, 1897. U.S. Dept. of Agriculture, Division of Botany. Washington, DC: U.S. Government Printing Office. 85 p.

Leiberg, John B. 1899. Present conditions of the forested areas in northern Idaho outside the limits of the Priest River Forest Reserve and north of the Clearwater River. In: Nineteenth Annual Report of the United States Geological Survey to the Secretary of the Interior, 1897-98, Charles D. Wolcott, Director: Part V -- Forest Reserves, Henry Gannett, Chief of Division of Geography and Forestry. Washington, DC: U.S. Government Printing Office. 14 p.

Leiberg, John B. 1899. The Priest River Reserve. In: Nineteenth Annual Report of the United States Geological Survey to the Secretary of the Interior, 1897-98, Charles D. Wolcott, Director: Part V -- Forest Reserves, Henry Gannett, Chief of Division of Geography and Forestry. Washington, DC: U.S. Government Printing Office. Pgs. 217-252.

Leiberg, John B. 1900. Sandpoint Quadrangle, Idaho. In: chapter by Gannett, Henry, Classification of lands. In: U.S. 56th congress, 2nd Session, House of Representatives, Document No. 5: Annual Reports of the Department of the Interior For the Fiscal Year Ended June 30, 1900 -- Twenty-First Annual Report of the United States Geologic Survey, Charles D. Wolcott, Director, Part V. Washington, DC: U.S. Government Printing Office. Pgs. 583-595.

Losensky, B. John. 1993. Historical vegetation in Region One by climatic section. (Draft report Revision 3 -- on file in Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region, Regional Office).

Mack, Richard N.; Rutter, N. W.; Valastro, S. 1983. Holocene vegetational history of the Kootenai River Valley, Montana. Quaternary Research. 20: 177-193.

McGarigal, Kevin; Marks, Barbara J. 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. Gen. Tech. Rep. PNW-GTR-351. Portland, OR: USDA, Forest Service, Pacific Northwest Research Station. 122p.

Mehringer, Peter J. Jr. 1985. Late-quaternary pollen records from the Interior Pacific Northwest and Northern Great Basin of the United States. In: Bryant, V. M., Jr. and Holloway, R. G., eds. Pollen records of late-Quaternary North American sediments. Dallas, TX: American Association of Stratigraphic Palynologists; 1985: 167-189.

Meyer 2005 – Art needs to provide citation

Millar, Constance I.; Woolfenden, Wallace B. 1999. The role of climatic variability in interpreting historical variability. Ecological Applications, 9(4):1207-1216.

Mullan, John. 1863. Report on the Construction of a Military Road from Fort Walla-Walla to Fort Benton (1859-1861). Washington DC: Government Printing Office.

Nonaka, Etsuko; Spies, Thomas A. 2005. Historical range of variability in landscape structure: a simulation study in Oregon, USA. Ecological Applications. 15(5): 1727-1746.

Parsons and others 1999 – Art needs to provide citation

Reynolds 2003 – Art needs to provide citation

Schmidt, K.M., Menakis, J.P. Hardy, C.C., Hann, W.J., Bunnell, D.L. 2002. *Development of coarse-scale spatial data for wildland fire and fuel management*. General Technical Report, RMRS-GTR-87, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Stevens, Issac I. 1855. Narrative and final report of explorations for a route for a Pacific railroad near the forty-seventh and forty-ninth parallels of northern latitude, from St. Paul to Puget Sound. (published in 1860 as: Reports of Explorations and Surveys to Ascertain The Most Practical and Economical Route For a Railroad From the Mississippi River To the Pacific Ocean – Made Under the Direction of the Secretary of War, In 1853-5. [In several books and volumes.] U.S. House of Representatives: 36 Congress, 1st Session. Ex. Doc. No. 56). Washington, DC: Thomas H. Ford, Printer. (This is known as the Stevens Expedition after Washington Territorial Governor Isaac I. Stevens, who headed the expedition.)

Tinkler, Daniel B.; Romme, William H.; Despain, Don G. 2003. Historic range of variability in landscape structure in subalpine forest of the Greater Yellowstone area, USA. Landscape Ecology. 18: 427-439.

USDA Forest Service, 1999. Vegetation Response Unit Characterizations and Target Landscape Prescriptions. Northern Region, Kootenai National Forest.

USDA, Forest Service, Northern Region. 1998. Northern Region overview. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region (posted on Forest Service Northern Region website). (192 p. detailed report + 46 p. summary + Misc. maps)

USDA, Forest Service. 1996. Status of the interior Columbia Basin: summary of scientific findings. Gen. Tech. Rept. PNW-GTR-385. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research station; U.S. Department of the Interior, Bureau of Land Management. 144 p.

Veblen, Thomas T. 2003. Historic range of variability of mountain forest ecosystems: concepts and applications. The Forestry Chronicle. 79: 223-226.

Weisberg, Peter, J. 2004. Importance of non-stand-replacing fire for development of forest structure in the Pacific Northwest, USA. Forest Science. 50(2): 245-258.

Whitlock, Cathy. 1992. Vegetational and climatic history of the Pacific Northwest during the last 20,000 years: implications for understanding present-day biodiversity. Northwest Environmental Journal. 8 (1): 5-28.

Wilson, Andrea M. and Patrick D. Miles. 2000. *Forest Resources of the Kootenai National Forest.* USDA Forest Service. Rocky Mountain Research Station. Ogden, UT.

Wimberly, Michael C.; Spies, Thomas A.; Long, Colin J.; Whitlock, Cathy. 2000. simulating historic variability in the amount of old forests in the Oregon coast range. Conservation Biology. 14 (1): 167-180.