BRITISH COLUMBIA

Ministry of Forests and Range

Decay Estimation for Interior Lodgepole Pine

a backgrounder

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September 2006

June 13, 2007

Revenue Branch

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INTRODUCTION

The purpose of this document is to provide some context with respect to the accuracy of the current and proposed methods to estimate the amount of decay in Interior lodgepole pine. Revenue Branch currently uses the Forest Inventory Zone (FIZ)-based 1976 Metric Diameter Class Loss Factor Tables to determine the decay reduction percentage for net volume estimation in timber cruising for appraisal purposes. Net factoring with the application of Net Volume Adjustment Factors (NVAF) has been proposed as an alternative to the current loss factor system of decay estimation. This document provides an historical context and overview of the current loss factors and compares the loss factor decay estimates with actual decay from destructively sampled lodgepole pine trees from a more recent unbiased sample database. While this report will focus on the decay losses associated with Lodgepole Pine; it is recognized that the waste and breakage appraisal cruise components also need to be addressed, especially in light of the current Mountain Pine Beetle epidemic.

Next steps that would be needed to improve decay estimation are suggested.

This document was prepared for Revenue Branch and the Interior Cruising Advisory Committee (ICAC) with input from Keith Tudor (Revenue Branch) and Will Smith (Forest Analysis and Inventory Branch).

FIZ-BASED LOSS FACTORS

The "Metric Diameter Class Loss Factor Tables" that are used to estimate percentage reduction for decay in valuation cruising were developed and published in 1976. The tables were produced by Forest Inventory Zones[1] (FIZ) or FIZ groupings and were specific for particular species and age classes (younger immature, older immature and mature). Within each table, percent decay reduction was provided by 5 cm dbh class in each of three decay "risk groups[2]". These tables were referred to as the "zonal" tables to differentiate them from a more limited number of "local" tables that were developed using data from local (usually PSYU level) studies.

For Interior lodgepole pine, there are 6 zonal loss factor tables, each differentiated by FIZ and age grouping (Table 1). In addition, Revenue Branch currently recognizes 2 local tables for interior lodgepole pine[3].

[1] A map showing the FIZ boundaries is shown for reference in Appendix A.
[2] "risk group" is defined based on the presence or absence of a list of 8 external pathological indicators.
[3] Series 897 (Kettle and TFL 8) and Series 898 (for Older Immature in the Chilko & Stum PSYUs).

Table 1: Zonal loss factor tables for interior lodgepole pine.

Table Series Number	*FIZ*	*Age*
801	All interior FIZs (D through L)	YI – younger immature 0 to 60 years
803	FIZ G through L	OI – older immature 61-120 years
804	FIZ D, E & F	OI – older immature 61-120 years
811	FIZ J	M – mature 121+ years
812	FIZ G, H, I, K & L	M – mature 121+ years
813	FIZ D, E & F	M – mature 121+ years

The development of these loss factor tables was based on decay study data (destructive sampling) collected for over 8000 lodgepole pine trees in the interior up to 1976. The loss factor tables were based on hand-drawn curves fit over scatterplots and diameter class average plots of this data. These curves were drawn to ensure consistent relationships by diameter class (i.e. decay generally increased as dbh increased) and risk group (decay always increased as risk group increased). The values in the current loss factor tables were then generated from these hand-drawn curves. The current FIZ-based loss factor relationships are shown in Figures 1 to 4 below. Note that the decay percentages for loss factor table Series 811 and 812 are identical. The decay percentage reduction factors for table Series 801 are all zero hence are not shown graphically.

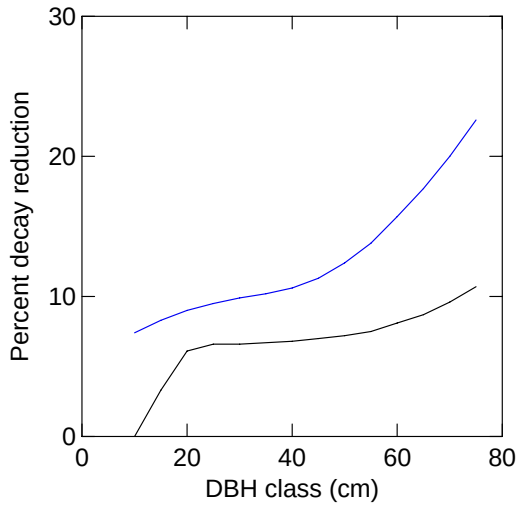


Figure 1: Series 803. Older immature (61 to 120 years), FIZ G through L. The black line is for risk group 1 and the blue line is for risk group 2 (risk group 3 is not applicable for this series).

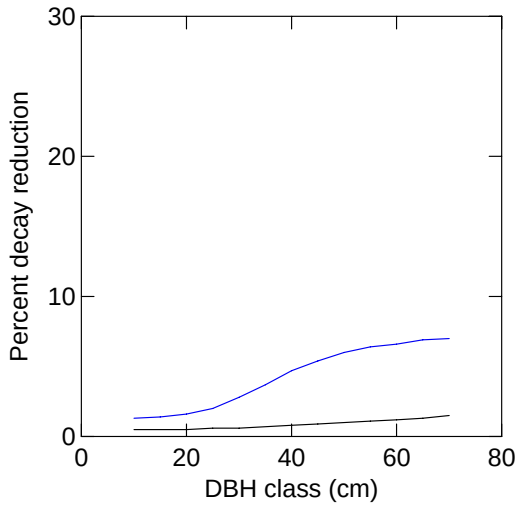


Figure 2: Series 804. Older immature (61 to 120 years), FIZ D, E & F. The black line is for risk group 1 and the blue line is for risk group 2 (risk group 3 is not applicable for this series).

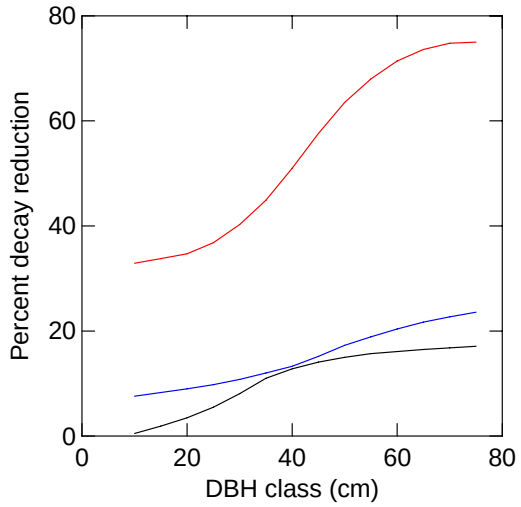


Figure 3: Series 811 & 812. Mature (121+ years), FIZ G to L. The black line is for risk group 1, the blue line for risk group 2, and the red line for risk group 3.

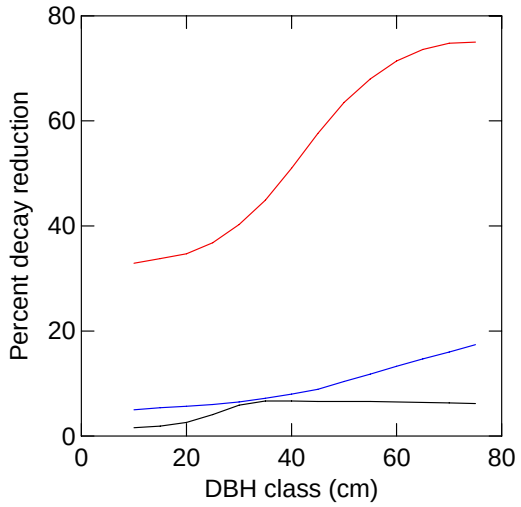


Figure 4: Series 813. Mature (121+ years), FIZ D, E & F. The black line is for risk group 1, the blue line is for risk group 2, and the red line is for risk group 3.

However, there were significant problems identified with both the underlying data itself and the approach used to fit the hand-drawn curves. A major issue was that the samples in the database were selected subjectively rather than being randomly chosen[4]. Stands with high decay were often targeted for sampling hence it is likely that these types of stands may be over-represented in the database. The hand-drawn nature of the curves also caused potential bias in the resulting loss factors. In the curve fitting process, there was a tendency to "chase the high defect samples"[5] and hence provide conservative estimates of volume. The bias in the hand-drawn curves became more apparent when Inventory Branch refit the loss factor curves using regression techniques in 1995 (see BEC-based loss factor discussion below).

DECAY ESTIMATION ALTERNATIVES

BEC-Based Loss Factors

In 1995, the hand-drawn FIZ-based loss estimation curves were refit based on Biogeoclimatic Ecosystem Classification (BEC) stratification. In addition to the difference in stratification, the new BEC-based loss factors also incorporated additional sample tree data collected between 1976 and 1995. More importantly, the curves were not hand-fit; modern regression techniques were used to develop the decay relationships.

Although the BEC-based loss factors were seen as an improvement over the FIZ-based curves, they were still not without bias. The majority of the sample data was the same (i.e. pre-1976) and even the additional samples collected between 1976 and 1995 were selected subjectively and hence were subject to bias[6]. As a result of the bias associated with both the FIZ-based and BEC-based loss factors, Inventory Branch began implementing a new system for decay estimation in 1996.

[4] Nor were they selected with known probability. Certain types of non-random sampling can also produce unbiased estimates as long as the selection probabilities and sample weights can be calculated.
[5] Will Smith, pers. comm..
[6] http://www.for.gov.bc.ca/hts/vri/ip/treevol.html#3

Net Factoring and NVAF

In an effort to address the bias and short-comings of the BEC-based loss factors, a new process called net factoring in combination with a Net Volume Adjustment Factor (NVAF) was introduced for inventory purposes. Net factoring involves the cruiser providing an estimate of visible decay based on a consistent set of rules and external decay indicators. At the volume compilation stage, a further adjustment factor (the Net Volume Adjustment Factor or NVAF) is applied to account for hidden decay and residual bias in the taper function. The NVAFs are developed at a management unit level for various species and/or maturity strata. Development of the NVAF requires specific sampling within the management unit and is accompanied by strict procedures for sample and tree selection to ensure that the sample is unbiased. Sampling for NVAF is an integral part of the provincial Vegetation Resources Inventory (VRI) program. NVAF sampling and the VRI program is ongoing and has yet to be implemented across the entire interior of the province.

LODGEPOLE PINE DECAY IN THE CURRENT NVAF DATABASE

The current destructive sampling database was collected for NVAF estimation and is unbiased. That is, samples were either randomly selected or were selected with known selection probabilities thus enabling unbiased estimation of NVAF values. For interior lodgepole pine, this database includes 338 live trees and 118 dead trees[7], each of which has been destructively sampled so that the actual decay percentage is known. The distribution of the live lodgepole pine trees by FIZ is shown in Table 2 below. For reference, a map showing FIZ boundaries is provided in Appendix A. A comparison of the distribution of samples in the NVAF database with the distribution of samples in the 1976 Loss Factor database is provided in Appendix B.

Table 2: Distribution of live lodgepole pine trees in the NVAF destructive sampling database.

	Interior FIZ									*total*
	D	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	
n	83	0	0	29	171	23	0	0	32	338

NVAF sampling has not been completed across the entire interior. This is illustrated by the patchy distribution of samples by FIZ in Table 2.

The sample weights that would be required to produce interior-wide estimates of decay percentage have not yet been calculated for the NVAF dataset. However, some general trends are apparent from the unweighted graphs of the actual decay for the trees in the NVAF destructive sampling database compared with the loss factor estimates of decay for the same trees[8].

The loss factor estimates of decay in live lodgepole pine trees with no external decay indicators appear to be overestimated. Among the 85 such samples in the NVAF database, only two samples had more than 1% actual decay. However, the loss factor tables provided estimates of

[7] The dead tree decay was not examined in this report. Additional descriptors, i.e. standing versus fallen dead, were not available for all dead trees in the dataset at the time of the analysis.

[8] Of the 338 live lodgepole trees in the NVAF database, there were 78 trees for which "local" loss factors were available (i.e. table series 898). The loss factor estimates of decay shown in the graphs use the "local" loss factor tables where applicable and the appropriate "zonal" loss factor tables elsewhere.

decay greater than 1% for 45 of these 85 sample trees (see figure 5). The age of these trees ranged from 41 to 247 years, with 52 trees being classed as older immature and 23 trees classed as mature.

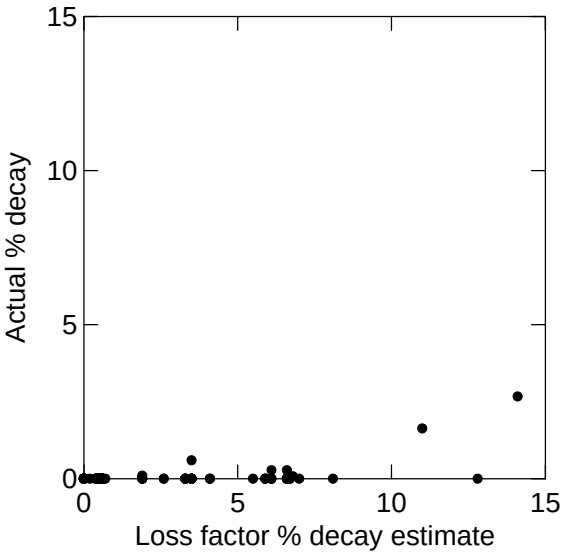


Figure 5: Live interior lodgepole pine trees in the NVAF database with no external pathogical indicators (n=85).

There were 253 live lodgepole pine trees in the NVAF database that showed at least one external pathological indicator. Of these, there were only 21 trees for which the actual decay percentage exceeded the loss factor estimate of decay. For over 88% of these 253 trees, the current loss factors overestimate decay[9].

The difference between the actual decay % and the estimated decay % using the 1976 loss factors is shown in Figure 6 as a function of dbh. Note that points falling below the horizontal dashed line represent trees for which decay was overestimated by the loss factors[10].

[9] There were an additional 9 trees where the loss factor decay % was exactly equal to the actual decay %. Hence there were 223 trees where the estimated loss factor decay % was greater than the actual decay %.
[10] There are 250 points on Figure 6. Three trees that indicated conk or blind conk were excluded from this graph.

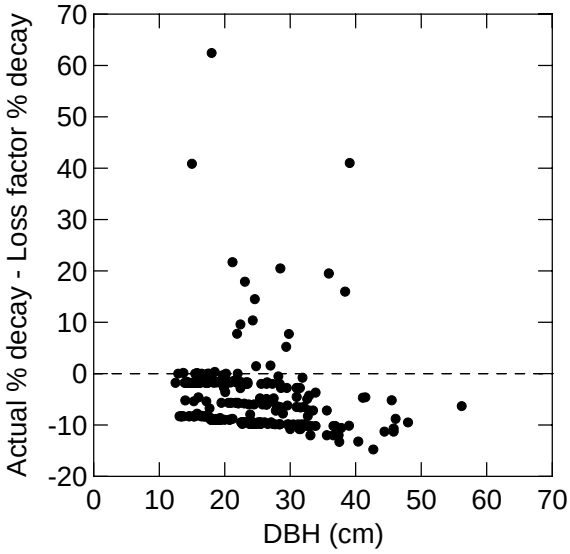


Figure 6: Live interior lodgepole pine trees in the NVAF database with external pathogical indicators (except conk and blink conk) (n=250).

The patterns in the loss factor decay overestimation apparent in Figure 6 are an artifact of the hand-drawn curves used to produce the loss factor tables. This can be seen more clearly when Figure 7 (a subset[11] of Figure 6) is compared with Figure 8. The curve shown on Figure 8 represents the decay % values in the loss factor table (Series 811/812) plotted as a function of dbh. The actual decay % for the trees in the NVAF database for which this loss factor table would apply have been overlain on this graph. In effect, Figure 7 shows the vertical difference (i.e. the difference in decay %) between the data points and the curve shown in Figure 8.

[11] The subset corresponds to mature trees, FIZ G through L, risk group 2 (i.e. loss factor table series 811/812, risk group 2).

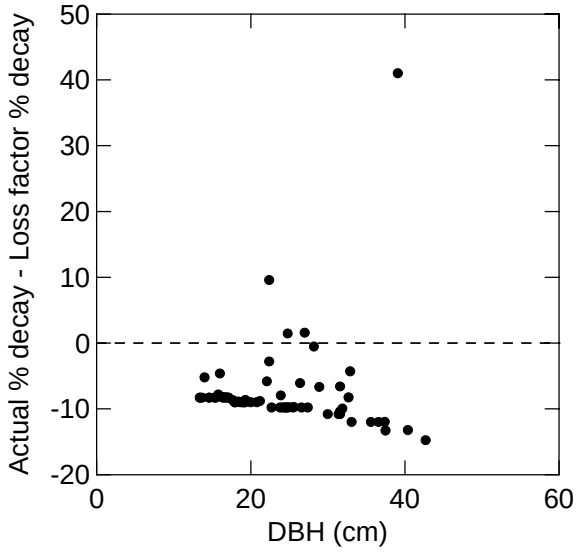


Figure 7: NVAF database trees corresponding to loss factor table series 811/812, risk group 2 (n=67).

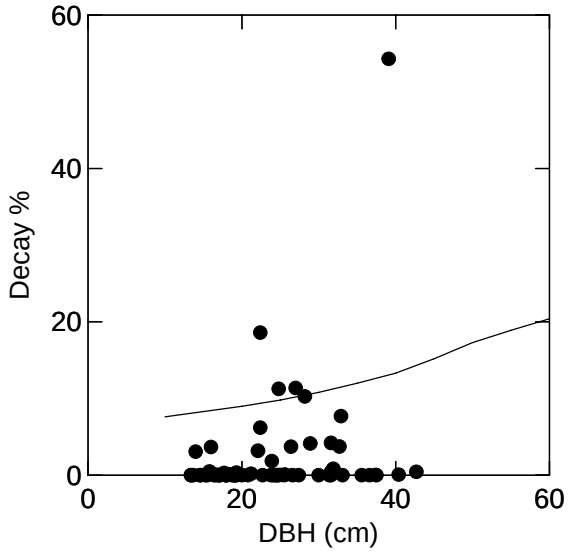


Figure 8: Curve corresponding to loss factor table series 811/812, risk group 2 as a function of dbh. Data points are actual decay % from NVAF database.

Graphs for other loss factor tables and risk groups in a format similar to Figure 8 are shown in Appendix C[12]. Note that these graphs and the observations in the following paragraphs pertain to *live* lodgepole pine trees.

In examining Figures 7 and 8 and the graphs in Appendix C, it is apparent that the relationships between estimated decay and dbh, risk group and FIZ that are implied by the loss factor tables (i.e. the curves on the graphs) appear to be overstated when compared to actual decay data. Even when these loss factor relationships (i.e. the curves) are compared with the historical data that was used as the basis for their development, the correspondence is relatively poor[13].

The differential in decay % related to age (i.e. older immature compared with mature) and location (i.e. the southern-most FIZs – D, E & F compared with the FIZs in the northern and central Interior – G through L) that is implied in the loss factor tables is not apparent in the actual decay for the trees in the current NVAF database. This is illustrated in Figure 9 for live lodgepole pine trees in risk group 2.

For example, the red and blue circled clusters of points in Figure 9 correspond to the observed loss factor decay overestimation for *older immature* trees in FIZ D, E & F (Loss Factor Table Series 804) and in FIZ G through L (Loss Factor Table Series 803) respectively. The graph shows that the FIZ-related difference in decay suggested by the loss factors[14] is likely not warranted for trees in the older immature age grouping. Similarly, the age-related differences in

[12] Refer to the even numbered figures in Appendix C i.e. figure C-2, C-4 etc.
[13] Refer to the odd numbered figures in Appendix C i.e. figure C-1, C-3 etc. These appendix figures show the loss factor curves overlain with the dbh class average decay for corresponding data in the historical decay database.
[14] Refer to Figures 1 and 2 once again to see the FIZ difference suggested by the loss factors.

the loss factors for risk group 2 (older immature compared with mature) in FIZ D, E & F are also likely not warranted[15].

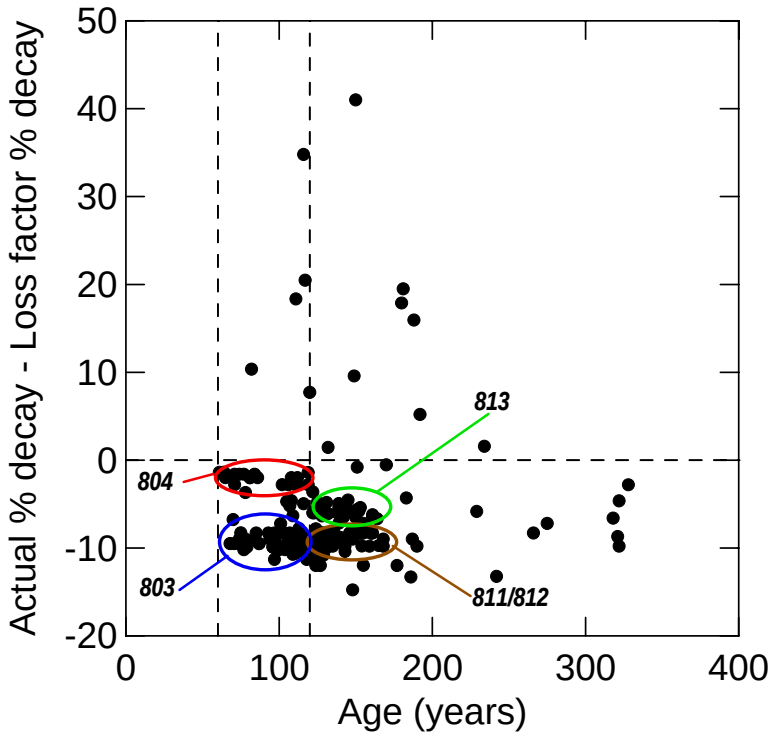


Figure 9: Patterns in loss factor decay estimation bias for live, risk group 2 lodgepole pine trees in the current NVAF database. Bias trends by age (older immature versus mature) and by location (FIZ D, E, F versus FIZ G through L) are highlighted. The red-circled cluster of points indicates a general bias for loss factor table series 804 (OI, FIZ DEF), the blue-circled cluster of points corresponds to loss factor table series 803 (OI, FIZ G-L), the green-circled cluster corresponds to loss factor table series 813 (M, FIZ DEF) and the brown-circled cluster corresponds to loss factor table series 811/812 (M, FIZ G-L).

SUMMARY AND DISCUSSION

An examination of the historical development of the current FIZ-based loss factors suggests that they may be biased. When the decay estimates based on these loss factors are compared to actual decay from lodgepole pine trees in the current NVAF destructively sampled database, the decay overestimation bias associated with the loss factors becomes more apparent. As a result, cruise-based estimates of net volume for lodgepole pine in the interior may be biased and volume may be underestimated.

[15] Compare the bias for the red circled points with the bias for the green circled points. If the loss factor decay % did not change from older immature to mature, then the green circled points would have been on approximately the same horizontal level (i.e. same level of bias) as the red circled points. However, because the loss factors overestimated the effect of age on decay, we see that the green circled points (i.e. mature trees) have more bias in their estimated decay %. Note that there are only minimal age-related differences in decay estimation bias between the blue circled points and the brown circled points. This is consistent with the minimal differences between the estimates of decay for older immature and mature trees that we see in the loss factor tables for FIZs G-L.

Moving toward a loss estimation system based on cruiser-called net factoring accompanied by the application of an unbiased NVAF would likely offer a substantial improvement in net volume estimation over the current FIZ-based loss factor approach. However, adoption of this alternative decay estimation system would require further analysis of the sufficiency of the existing sampling distribution in the NVAF database.

In the short term, there are a number of potential options for improving the efficiency of the current loss factor system. These might include:

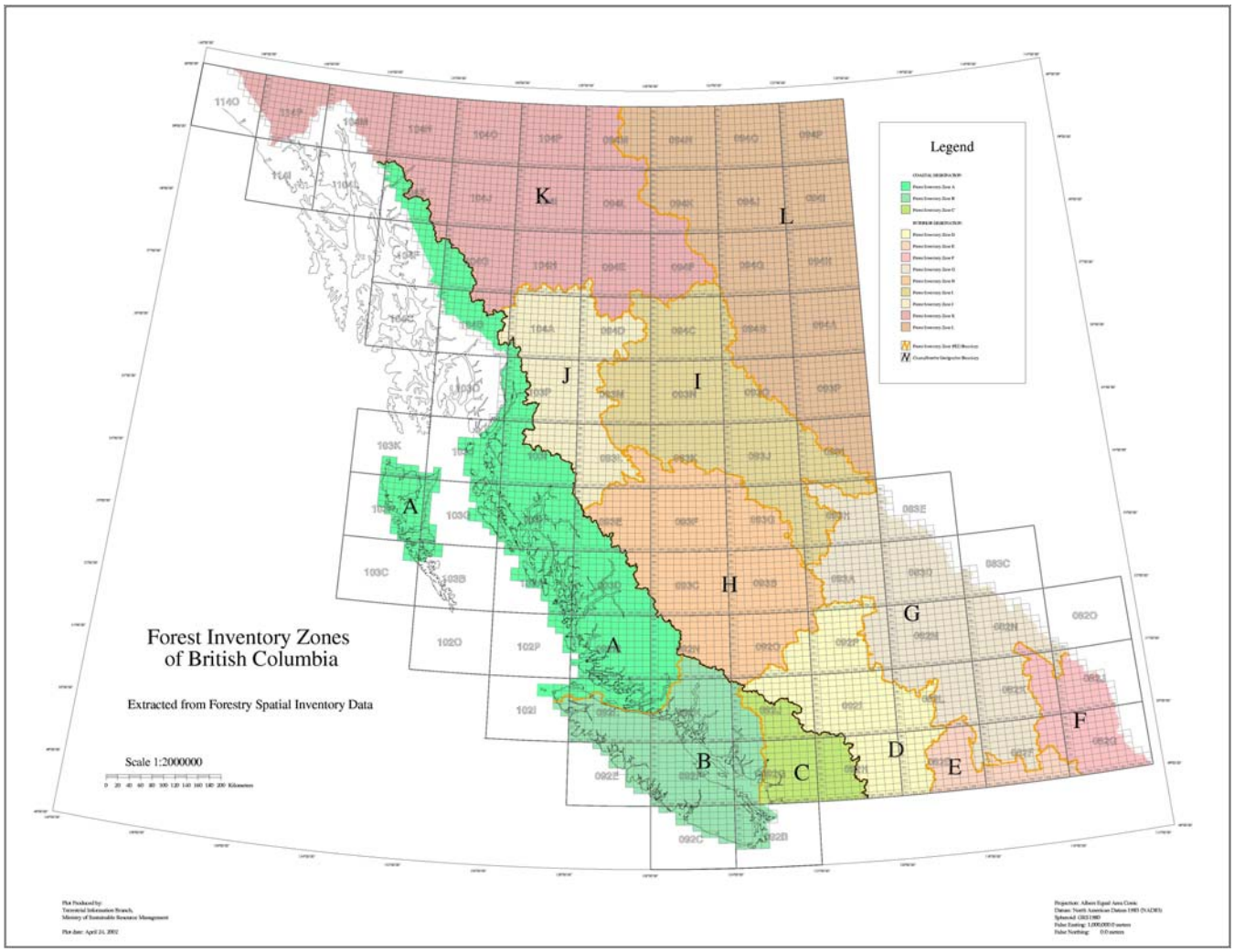
1. Status quo (no changes to current FIZ-based loss factor system).
2. Flat factors by FIZ-grouping; the use of local factors; modified age class breaks.
3. Flat factors by FIZ-grouping; the use of local factors; no age class breaks.
4. Flat factor for all FIZ and ages.

In the longer term, the following tasks should be considered:

1. Complete a gap analysis for the current NVAF destructive sampling database. The sufficiency of the existing distribution of sample trees should be assessed and areas requiring further sampling should be identified within regional inventory plans.
2. Derive the appropriate sample weights for the existing NVAF trees.
3. Derive specific adjustment factors for decay and taper.
4. Examine the accuracy of the current waste and breakage factors relative to the current MPB epidemic.

Apart from the bias associated with the loss factor decay estimates, the cruise-based estimates of net volume may also be impacted by bias in the taper equations. In addition, the accuracy of breast height age and dbh and their effect on stump correction factors is another potential source of net volume estimation bias that should be examined.

APPENDIX A: MAP OF FOREST INVENTORY ZONE (FIZ) BOUNDARIES



APPENDIX B: SAMPLE DISTRIBUTION FOR LIVE INTERIOR LODGEPOLE PINE (1976 LOSS FACTORS AND NVAF)

Age & risk group stratum		*Sample Size for Live Lodgepole Pine by FIZ in the Historical 1976 Loss Factor Database and the current NVAF Database*																	
		D		E		F		G		H		I		J		K		L	
Risk group	*Age class*	*1976 LF*	*NVAF*	*1976 LF*	*NVAF*	*1976 LF*	*NVAF*	*1976 LF*	*NVAF*	*1976 LF*	*NVAF*	*1976 LF*	*NVAF*	*1976 LF*	*NVAF*	*1976 LF*	*NVAF*	*1976 LF*	*NVAF*
1	Imm	96	18	26	0	183	0	1	10	535	33	129	4	20	0	84	0	195	11
	Mature	6	8	35	0	9	0	5	1	443	11	252	1	80	0	139	0	47	3
2	Imm	171	25	60	0	217	0	1	13	1094	76	211	8	90	0	365	0	458	18
	Mature	50	32	58	0	41	0	21	6	1069	51	538	9	369	0	698	0	326	1
3	Imm	3	0	0	0	3	0	1	0	9	0	4	0	0	0	6	0	1	0
	Mature	4	0	4	0	0	0	4	0	13	0	10	1	13	0	24	0	0	0
	total	330	83	183	0	453	0	33	30	3163	171	1144	23	572	0	1316	0	1027	33

APPENDIX C: COMPARISON OF "ZONAL"[16] 1976 LOSS FACTOR TABLE ESTIMATES OF DECAY WITH HISTORICAL DATA AND CURRENT NVAF DATA, BY DBH FOR LIVE LODGEPOLE PINE TREES.

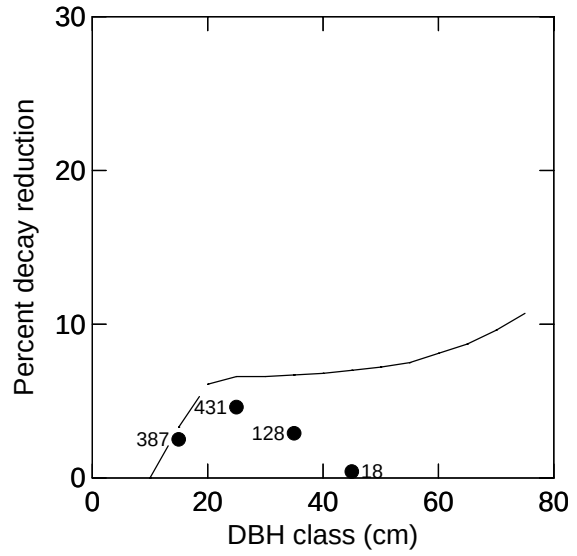


Fig. C-1: ***Series 803, risk group 1 & historical data***. The line represents the loss factor table values. The dots represent ***average*** decay percent in a 10cm dbh class from the historical interior lodgepole pine decay database[17].

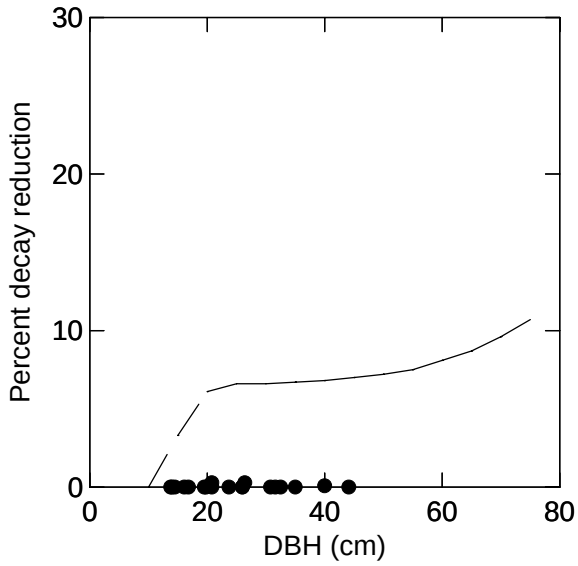


Fig. C-2: ***Series 803, risk group 1 & current data***. The line represents the loss factor table values. The dots are actual decay for trees in the current decay database (n=19). All points on this graph are "older immature" live trees as per the loss factor table definitions.

[16] Graphs for "local" loss factor tables are shown in appendix D.

[17] Note that although series 803 corresponds to "older immature", the historical average decay data points may also include younger immature trees (since younger and older immature were not differentiated in the query).

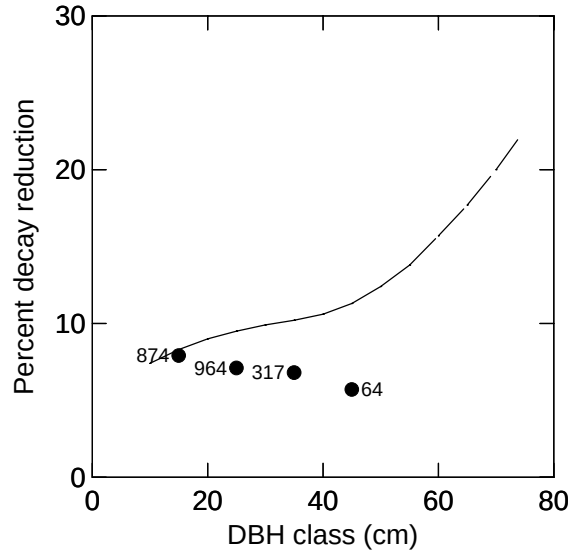


Fig. C-3: ***Series 803, risk group 2 & historical data***. The line represents the loss factor table values. The dots represent ***average*** decay percent in a 10cm dbh class from the historical interior lodgepole pine decay database.

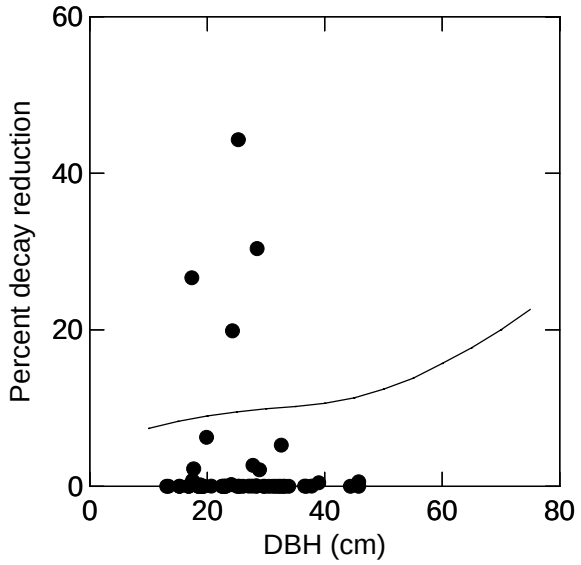


Fig. C-4: ***Series 803, risk group 2 & current data***. The line represents the loss factor table values. The dots are actual decay for trees in the current decay database (n=58). All points on this graph are "older immature" live trees as per the loss factor table definitions.

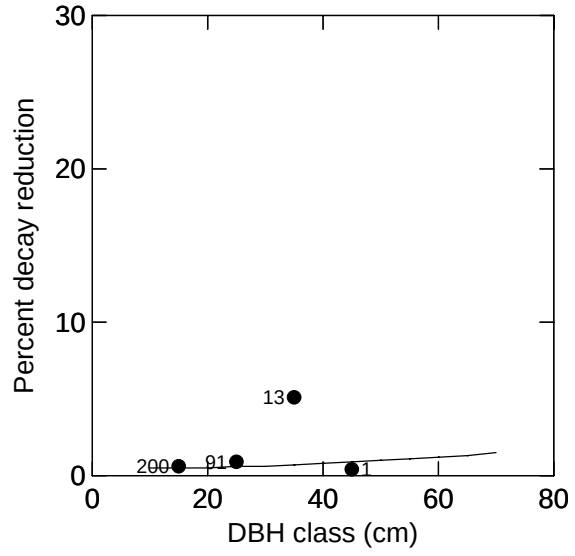


Fig. C-5: ***Series 804, risk group 1 & historical data***. The line represents the loss factor table values. The dots represent ***average*** decay percent in a 10cm dbh class from the historical interior lodgepole pine decay database[18].

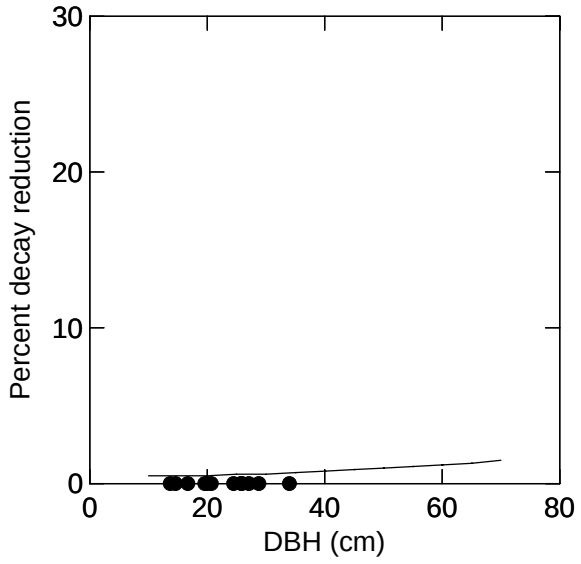


Fig. C-6: ***Series 804, risk group 1 & current data***. The line represents the loss factor table values. The dots are actual decay for trees in the current decay database (n=12). All points on this graph are "older immature" live trees as per the loss factor table definitions.

[18] Note that although series 804 corresponds to "older immature", the historical average decay data points may also include younger immature trees (since younger and older immature were not differentiated in the query).

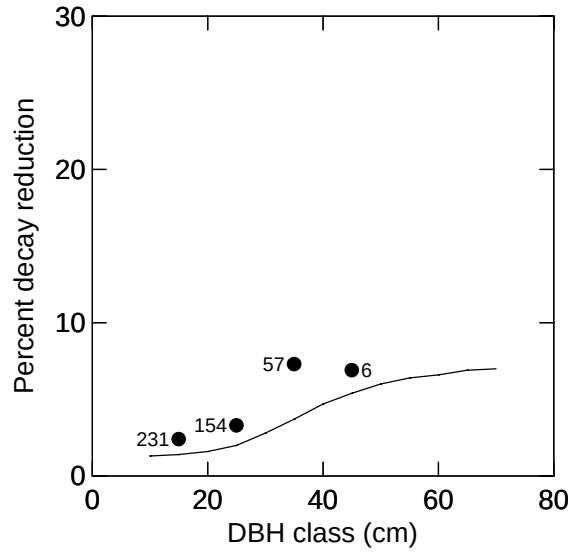


Fig. C-7: ***Series 804, risk group 2 & historical data***. The line represents the loss factor table values. The dots represent *average* decay percent in a 10cm dbh class from the historical interior lodgepole pine decay database.

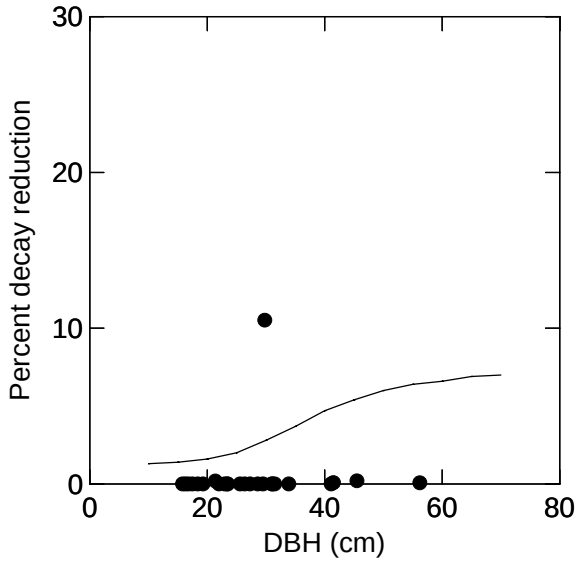


Fig. C-8: ***Series 804, risk group 2 & current data***. The line represents the loss factor table values. The dots are actual decay for trees in the current decay database (n=25). All points on this graph are "older immature" live trees as per the loss factor table definitions.

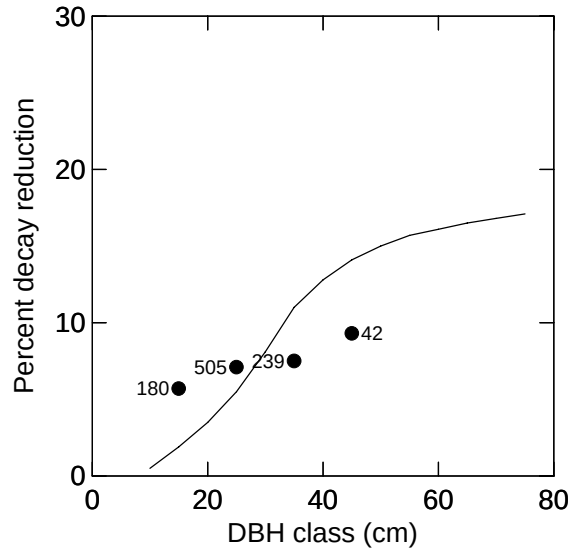


Fig. C-9: ***Series 811/812, risk group 1 & historical data***. The line represents the loss factor table values. The dots represent *average* decay percent in a 10cm dbh class from the historical interior lodgepole pine decay database.

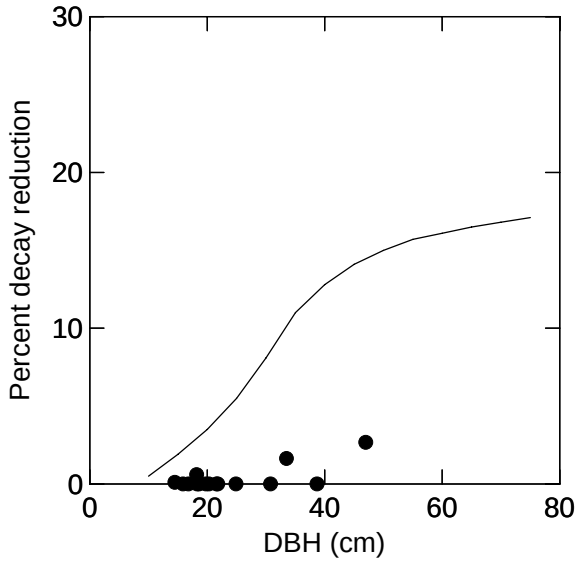


Fig. C-10: ***Series 811/812, risk group 1 & current data***. The line represents the loss factor table values. The dots are actual decay for trees in the current decay database (n=15). All points on this graph are "mature" live trees as per the loss factor table definitions.

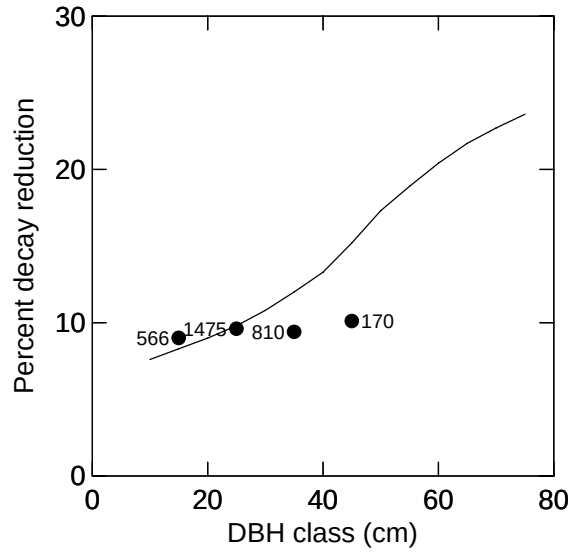


Fig. C-11: ***Series 811/812, risk group 2 & historical data***. The line represents the loss factor table values. The dots represent *average* decay percent in a 10cm dbh class from the historical interior lodgepole pine decay database.

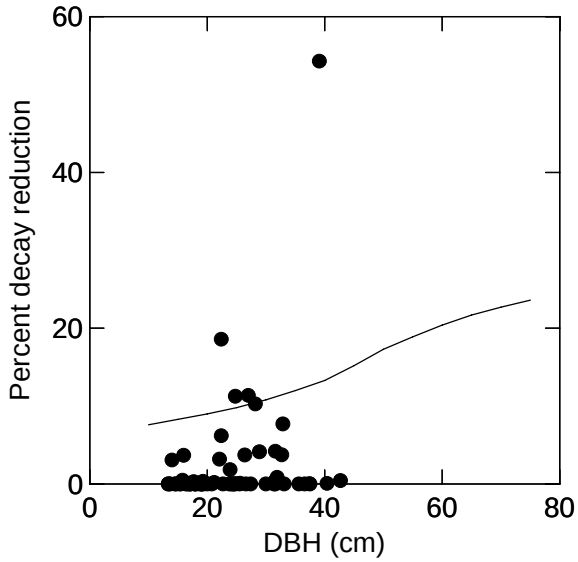


Fig. C-12: ***Series 811/812, risk group 2 & current data***. The line represents the loss factor table values. The dots are actual decay for trees in the current decay database (n=67). All points on this graph are "mature" live trees as per the loss factor table definitions.

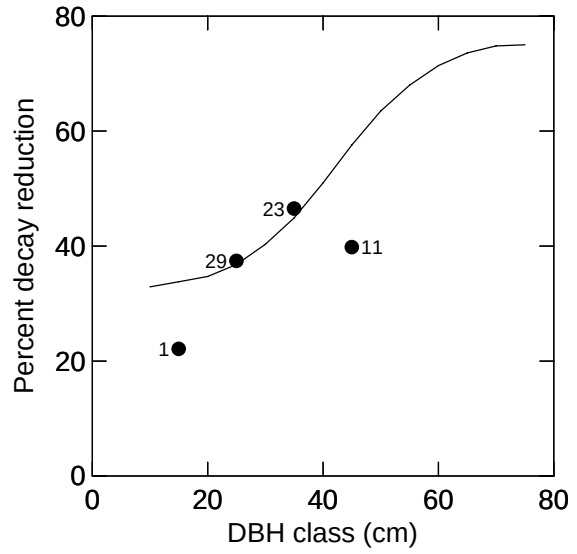


Fig. C-13: ***Series 811/812, risk group 3 & historical data***. The line represents the loss factor table values. The dots represent *average* decay percent in a 10cm dbh class from the historical interior lodgepole pine decay database.

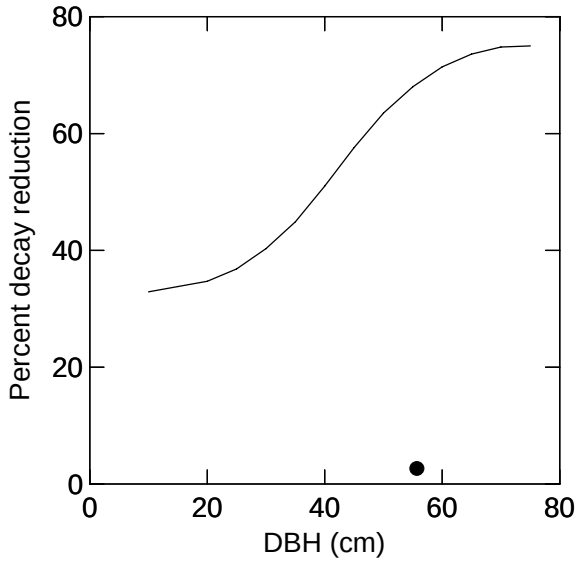


Fig. C-14: ***Series 811/812, risk group 3 & current data***. The line represents the loss factor table values. The dots are actual decay for trees in the current decay database (n=1). All points on this graph are "mature" live trees as per the loss factor table definitions.

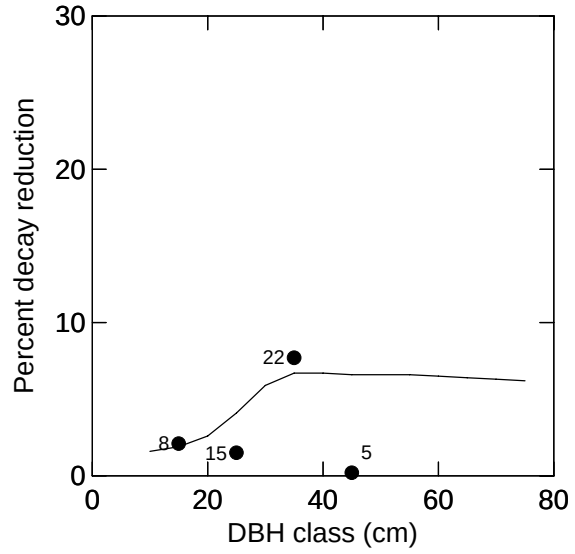


Fig. C-15: ***Series 813, risk group 1 & historical data***. The line represents the loss factor table values. The dots represent *average* decay percent in a 10cm dbh class from the historical interior lodgepole pine decay database.

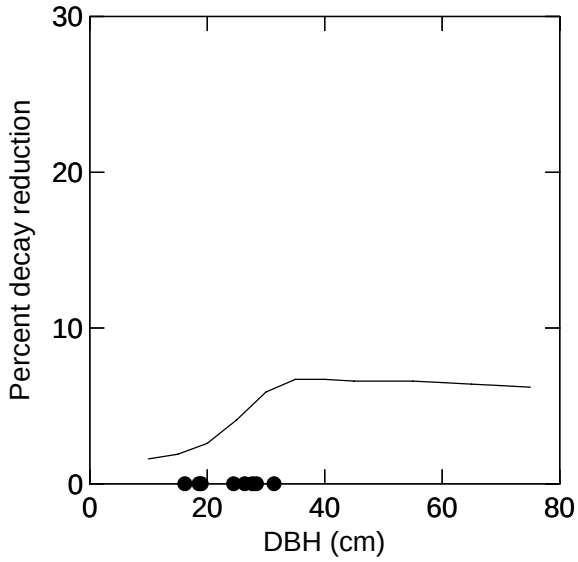


Fig. C-16: ***Series 813, risk group 1 & current data***. The line represents the loss factor table values. The dots are actual decay for trees in the current decay database (n=8). All points on this graph are "mature" live trees as per the loss factor table definitions.

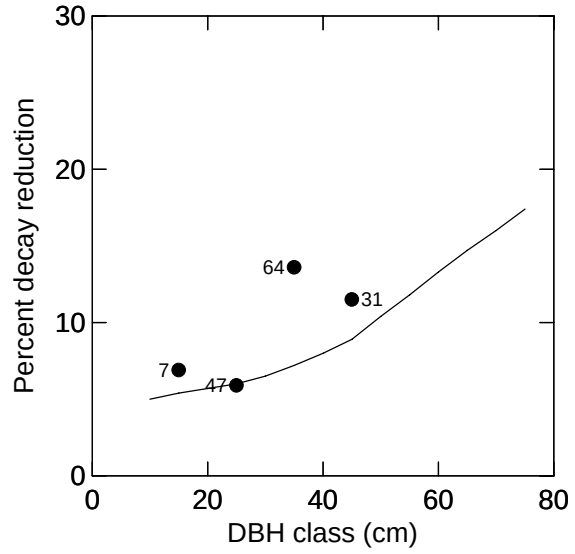


Fig. C-17: ***Series 813, risk group 2 & historical data***. The line represents the loss factor table values. The dots represent *average* decay percent in a 10cm dbh class from the historical interior lodgepole pine decay database.

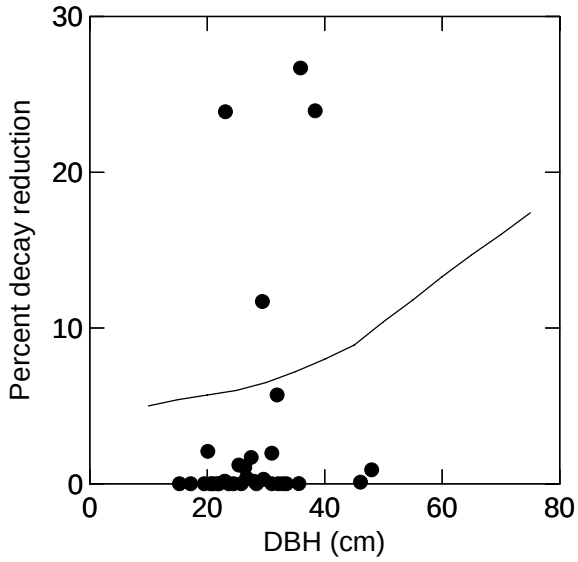


Fig. C-18: ***Series 813, risk group 2 & current data***. The line represents the loss factor table values. The dots are actual decay for trees in the current decay database (n=32). All points on this graph are "mature" live trees as per the loss factor table definitions.

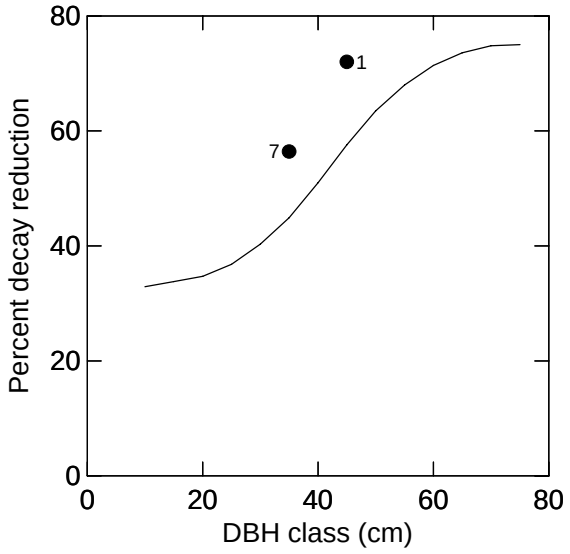


Fig. C-19: ***Series 813, risk group 3 & historical data***. The line represents the loss factor table values. The dots represent *average* decay percent in a 10cm dbh class from the historical interior lodgepole pine decay database.

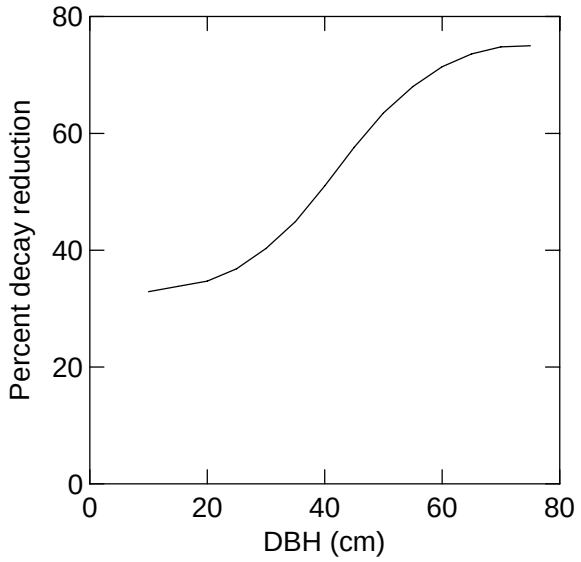


Fig. C-20: ***Series 813, risk group 3 & current data***. The line represents the loss factor table values. There were no mature (>120 years) live lodgepole pine sample trees from FIZ D, E or F in the current decay database.

APPENDIX D: COMPARISON OF "LOCAL"[19] 1976 LOSS FACTOR TABLE ESTIMATES OF DECAY WITH CURRENT NVAF DATA, BY DBH FOR LIVE LODGEPOLE PINE TREES.

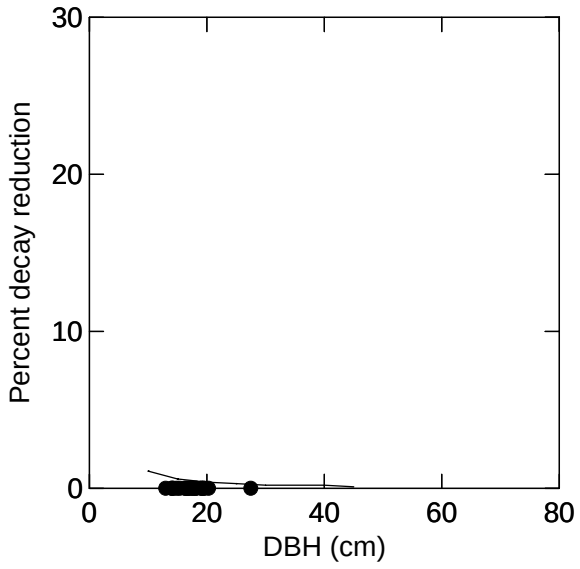


Fig. D-1: ***Series 898, risk group 1 & current data***. The line represents the loss factor table values. The dots are actual decay for trees in the current decay database (n=21). All points on this graph are "older immature" live trees as per the loss factor table definitions.

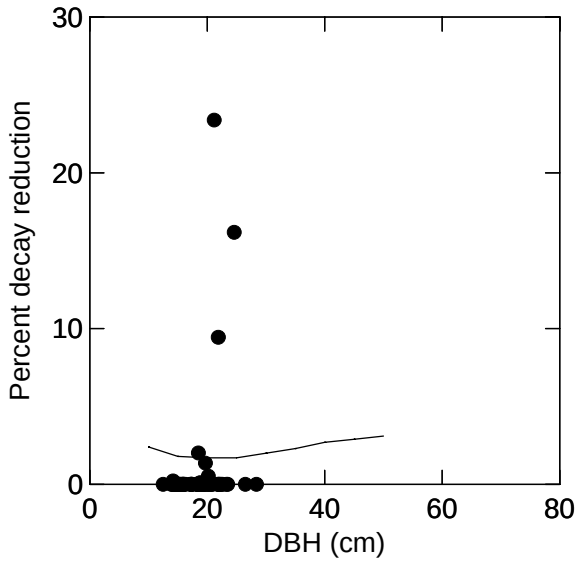


Fig. D-2: ***Series 898, risk group 2 & current data***. The line represents the loss factor table values. The dots are actual decay for trees in the current decay database (n=57). All points on this graph are "older immature" live trees as per the loss factor table definitions.

[19] The current NVAF data points shown on these graphs meet the criteria (age and geographic location) for using the local loss factor tables 898. There were no trees in the current NVAF database meeting the criteria for local loss factor table Series 897 hence the decay loss factor curves for Series 897 are not shown here.