Summary of 16 Years of Growth of Uneven-Aged Interior Douglas-fir with Different Stand Structures in the Alex Fraser Research Forest, Williams Lake, British Columbia (Project 88-3)

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Abstract

Six permanent sample plots were located in the spring of 1988 across a range of stand structures in an uneven-aged Douglas-fir stand in the Knife Creek Block of the UBC Alex Fraser Research Forest near Williams Lake, BC. Specific locations for the plots were chosen to reflect a diversity of stand densities and structures, although all areas selected had a wide range of size classes present. Plots 1 and 2 were located in relatively open portions of the stand, with the stand structure dominated by large dbh trees. Plots 3 and 4 were located in an area that was quite dense originally, but which had been spaced. These plots represent a stand structure dominated by mid-sized dbh trees. Plots 5 and 6 were established in an area dominated by large numbers of small dbh trees. Plots 1 through 4 are 0.1 ha in size and plots 5 and 6 are 0.05 ha in size to maintain uniform conditions within the plots and to keep the number of trees measured to a manageable size. The plots were measured upon establishment and re-measured following the 1992 growing season, and in the spring/summer of 1997 and 2004. For all re-measurements, the dbh of all living trees were measured in the early spring, prior to the onset of diameter growth; other measurements did not include current year foliage, so the re-measurements were inclusive of the 1992, 1996 and the 2003 growing seasons, respectively.

There was considerable variation in the growth of a number of stand attributes among plots within periods, and within the same plots among periods. This is due, in part, to the impact of mortality of larger trees on unit area growth; however, there were obviously other factors at play as well. There were no apparent trends by plot or stand structure when the data are viewed on a unit area basis. For example three different plots had the highest basal area growth for each of the three growth periods (88-92: Plot 6; 93-96: Plot 3; and 97-03: Plot 1).

Based on the growth of these six plots, established across a range of stand conditions, it appears that unit area growth in both basal area and volume is both highly variable and apparently insensitive to stand structure. If this holds over a wider area, it means that interior Douglas-fir stands can be maintained in a variety of stand structures, to meet a number of different objectives, without unduly sacrificing basal area and volume growth. The limits to where residual structures and densities begin to affect growth in unit area basal area and volume are not apparent from the range of stand structures examined in this study.

Acknowledgements

Introduction

Stands of uneven-aged interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) are structurally complex due to a history of disturbances from partial cutting, insects, and fire. They are an important source of timber in the central and southern interior of British Columbia (Marshall and Wang 1996). As well, many interior Douglas-fir stands provide important winter habitat for mule deer (*Odocoileus hemionus* Raf.) (Armleder *et al*. 1986).

Little was known on the dynamics of uneven-aged interior Douglas-fir in the mid-1980s (Johnstone 1985). In an effort to address this, six permanent sample plots (PSPs) were established in 1988 on the Knife Creek Block of the UBC Alex Fraser Research Forest, located near Williams Lake, BC. These PSPs were located in three distinct structural types in close proximity to one another (within 1 km) to document differences in the stand dynamics among these different structural types.

This report summarizes 16 years of growth on these PSPs. Some of the content of this summary has been taken from Marshall (1988), Marshall and Wang (1996), and Nienaber (1999).

Methods

The PSPs were located after reconnaissance of the area east of Pipeline Road and south of Jones Creek Road on the Knife Creek Block. Plots 1 to 4 were established on a portion of a 40 ha block that was partially harvested and precommercially thinned (juvenile spaced) in 1983, according to the criteria subsequently documented for maintenance of mule deer winter range (Armleder *et al*. 1986). There was also some evidence of previous light selective logging (probably in the 1950s for railway ties). Plots 5 and 6 were located in an adjacent block with no evidence of logging or spacing in the last 40 to 50 years. Specific locations for the plots were chosen to reflect a diversity of stand densities and structures, although all areas selected had a wide range of size classes present. The following description is taken directly from Marshall and Wang (1996).

"Plots 1 and 2 were located in relatively open portions of the block, with the stand structure dominated by large dbh trees. Plots 3 and 4 were located in an area that was quite dense originally, but which had been spaced. These plots represent a stand structure dominated by mid-sized dbh trees. Plots 5 and 6 were established in an area dominated by large numbers of small dbh trees. For ease of reference, Plots 1 and 2 will be referred to as the "large tree plots", plots 3 and 4 will be referred to as the "medium tree plots", and plots 5 and 6 will be referred to as the "small tree plots". Although attempts were made to make the conditions on each of the pairs of plots as similar as possible, some differences exist for all variables measured. Plots 1 through 4 are 0.1 ha (31.6 m × 31.6 m) in size and plots 5 and 6 are 0.05 ha (31.6 m × 15.8 m) in size. The smaller size of the later two plots was necessary to maintain uniform conditions within the plots and to keep the number of trees measured to a manageable size."

The plots were established and initial measurements taken during May through the first part of July, 1988. All trees greater than 1.3 m in height within the confines of the plot and those trees

greater than 10 cm dbh around the boundary of the plots (potential influence trees) were permanently tagged. The species of each tagged tree was recorded, along with measures of dbh, total tree height, height to the base of the live crown, crown width (in two directions), and vigor. The locations of all tagged trees were also mapped. The plots were first re-measured following the 1992 growing season. The dbh of each living tree was subsequently re-measured in the early spring of 1997 and 2004, prior to the onset of diameter growth; other measurements made in those years did not include current year foliage, so all measurements were inclusive of the 1996 and the 2003 growing seasons, respectively.

Changes in the Plots Through Time

Plot conditions at the time of establishment are given in Table 1. Almost all the trees were Douglas-fir. Two lodgepole pine (*Pinus contorta*) were found on Plot 5 and one on Plot 6, and one trembling aspen (*Populus tremuloides*) was found on Plot 6. The large tree plots (Plots 1 and 2) were moderately dense (Curtis' (1982) relative density (RD) values of around 10), and had a larger percentage of stems and basal area in trees greater than 20 cm dbh than the other plots. Nine trees, most of them among the largest in the plot, were removed from plot 1 by unauthorized cutting sometime before the first remeasurement. Their removal greatly influence plot structure, so the condition of the residual trees in Plot 1 at the time of establishment is also given in Table 1. The medium tree plots (Plots 3 and 4) were slightly less dense than the large tree plots (RD values around 8.5), with a larger percentage of stems and basal area in trees between 10 and 20 cm dbh than the other plots. Some unauthorized harvesting of a few large dead trees also took place on Plot 4, but only one small living tree was killed in the process. The small tree plots (Plots 5 and 6) were the densest of the plots (RD values of 13.4 and 10.3, respectively), and had the largest percentage of the stems and basal area in stems less than 10 cm dbh.

Table 1. Plot conditions at the time of establishment in 1988 (Marshall and Wang 1996).

Plot	Stems/ha	BA/ha (m²)	Dq[a] (cm)	RD[b]	Volume/ha[d] (m³)	Stems /ha < 10 cm	Stems/ha 10 - 20 cm	Stems/ha > 20 cm	BA/ha < 10 cm	BA/ha 10 - 20 cm	BA/ha > 20 cm
1	1610	43.61	18.57	10.12	360.9	72.6	12.4	14.9	4.6	6.4	89.0
1-C[c]	1520	24.29	14.26	6.43	190.4	75.0	12.5	12.5	7.8	10.8	81.3
2	1170	47.46	22.73	9.96	387.7	57.2	14.5	28.2	1.5	4.9	93.6
3	2520	29.46	12.20	8.43	191.5	64.2	31.0	4.8	9.4	41.3	49.3
4	1540	36.13	17.30	8.69	234.6	32.5	53.9	13.6	4.8	38.6	56.6
4-C[c]	1530	36.04	17.30	8.66	234.2	32.7	53.6	13.7	4.8	38.5	56.7
5	5660	41.48	9.66	13.35	272.2	88.0	6.0	6.0	15.9	14.8	69.3
6	4300	32.34	9.79	10.34	208.4	83.2	10.7	6.0	15.8	17.5	66.7

Percentage Composition by DBH Classes covers the last six columns.

[a] Quadratic mean diameter.
[b] Curtis' (1982) relative density.
[c] Values based on trees remaining after unauthorized cutting.
[d] Total volume per ha.

Plot conditions after the 1992 growing season are given in Table 2 and the change in conditions from 1988 through the 1992 growing season are given in Table 3. A smaller proportion of stems

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per ha were less than 10 cm in dbh following the 1992 growing season than in 1988 across all plots, although the proportion of basal area contributed by this size class decreased in some plots and increased in others. The overall number of stems per ha decreased in all plots due to mortality; the number of ingrowth trees was small, limited to 10 stems per ha (i.e., 1 tree) on Plot 2. The largest decrease in stems per ha (in both absolute and percentage terms) occurred on the small tree plots. The best basal area growth occurred on the medium tree plots and the best volume growth occurred on the large tree plots.

Table 2. Plot conditions following the 1992 growing season (Marshall and Wang 1996).

Plot	Stems/ha	BA/ha (m^2)	Dq^a (cm)	RD^b	Volume/ha^c (m^3)	Percentage Composition by DBH Classes					
						Stems /ha < 10 cm	Stems/ha 10 - 20 cm	Stems/ha > 20 cm	BA/ha < 10 cm	BA/ha 10 - 20 cm	BA/ha > 20 cm
1	1450	25.96	15.10	6.68	208.6	70.3	15.9	13.8	7.0	12.1	60.8
2	1140	48.43	23.26	10.04	407.9	56.1	14.9	28.9	1.6	5.2	93.2
3	2440	31.30	12.78	8.76	209.5	62.7	31.1	6.1	9.7	39.5	50.8
4	1500	37.68	17.88	8.91	250.9	28.7	53.3	16.0	4.5	36.9	58.6
5	5260	42.61	10.16	13.37	287.3	87.0	5.7	7.2	16.4	11.3	72.2
6	4140	34.21	10.26	10.68	223.3	82.6	11.1	6.3	16.2	18.2	65.6

[a] Quadratic mean diameter.
[b] Curtis' (1982) relative density.
[c] Total volume per ha.

Table 3. Change in structural conditions of plots (1988 to 1992, inclusive).

Plot #	Changes									
	Stems/ha (Period)	Stems/ha (Yearly)	BA/ha (Period)	BA/ha (Yearly)	Dq^a (Period)	Dq (Yearly)	RD^b (Period)	RD (Yearly)	Volume/ha^d (Period)	Volume/ha (Yearly)
1	-70	-15.6	1.67	0.37	0.87	0.19	0.27	0.06	18.2	4.04
2	-30	-6.7	0.97	0.22	0.53	0.12	0.08	0.02	20.2	4.49
Yearly^c Average		**-11.1**		**0.29**		**0.156**		**0.037**		**4.27**
3	-80	-17.8	1.84	0.41	0.58	0.13	0.33	0.07	18.0	4.00
4	-30	-6.7	1.64	0.36	0.58	0.13	0.25	0.06	16.7	3.71
Yearly^c Average		**-12.2**		**0.39**		**0.129**		**0.064**		**3.86**
5	-400	-88.9	1.13	0.25	0.50	0.11	0.02	0.00	15.1	3.36
6	-160	-35.6	1.87	0.42	0.50	0.11	0.34	0.08	14.9	3.31
Yearly^c Average		**-62.2**		**0.33**		**0.111**		**0.040**		**3.33**

[a] Quadratic mean diameter.
[b] Curtis' (1982) relative density.
[c] Assuming a growth period of 3.5 years, due to the establishment of the plots approximately halfway through the 1988 growing season.
[d] Total volume per ha.

Plot conditions following the 1996 growing season are given in Table 4 and the changes from the 1992 growing season are given in Table 5. Ingrowth occurred on Plots 1 and 2 (90 and 60 stems/ha, respectively) and exceeded mortality (30 and 20 stems/ha, respectively) on these plots. The lowest growth in basal area for the 1993 to 1996 period occurred on Plot 2 (1.94 m^2/ha); the

other plots displayed relatively similar basal area growth, ranging from 2.44 m²/ha (Plot 5) to 3.32 m²/ha (Plot 3). The largest increase in quadratic mean diameter occurred in the medium tree plots, averaging 0.223 cm/year. The small tree plots averaged the highest volume growth (4.79 m³/ha/year), followed by the medium tree plots and the large tree plots (3.00 and 2.86 m³/ha/year, respectively). However, there was considerable variation in volume growth plot-to-plot, even within the same structural type.

Table 4. Plot conditions following the 1996 growing season.

Plot	Stems/ha	BA/ha (m²)	Dq[a] (cm)	RD[b]	Volume/ha[c] (m³)
1	1510	28.20	15.42	7.18	224.1
2	1180	50.37	23.32	10.43	415.3
3	2350	34.62	13.70	9.35	216.8
4	1460	40.24	18.74	9.30	267.6
5	5020	45.05	10.69	13.78	302.5
6	4000	37.52	10.93	11.35	246.4

[a] Quadratic mean diameter.
[b] Curtis' (1982) relative density.
[c] Total volume per ha.

Table 5. Change in structural conditions of plots (1993 to 1996, inclusive).

Plot #	Stems/ha (Period)	Stems/ha (Yearly)	BA/ha (Period)	BA/ha (Yearly)	Dq[a] (Period)	Dq (Yearly)	RD[b] (Period)	RD (Yearly)	Volume/ha[c] (Period)	Volume/ha (Yearly)
1	60	15.0	2.24	0.56	0.32	0.08	0.50	0.12	15.5	3.88
2	40	10.0	1.94	0.48	0.06	0.02	0.39	0.10	7.4	1.85
Yearly Average		12.5		0.52		0.047		0.111		2.86
3	-90	-22.5	3.32	0.83	0.92	0.23	0.59	0.15	7.3	1.82
4	-40	-10.0	2.56	0.64	0.86	0.22	0.39	0.10	16.7	4.18
Yearly Average		-16.2		0.74		0.223		0.123		3.00
5	-240	-60.0	2.44	0.61	0.53	0.13	0.41	0.10	15.2	3.80
6	-140	-35.0	3.31	0.83	0.67	0.17	0.67	0.17	23.1	5.78
Yearly Average		-47.5		0.72		0.150		0.135		4.79

[a] Quadratic mean diameter.
[b] Curtis' (1982) relative density.
[c] Total volume per ha.

Plot conditions following the 2003 growing season are given in Table 6 and the changes from the 1996 growing season are given in Table 7. Of particular note is the negative growth in basal area per ha and volume per ha on Plot 3. This is principally due to the death of two large trees (> 60 cm dbh) on the plot over this period. Other than Plot 3, the two small tree plots (Plots 5 and 6) showed the lowest growth in basal area per ha and volume per ha. Since these were the densest plots (both in terms of relative density and stems per ha), it is not surprising that the mortality on these plots, in terms of stems per ha that died over the period, was the highest.

Table 6. Plot conditions following the 2003 growing season.

Plot	Stems/ha	BA/ha (m^2)	Dq[a] (cm)	RD[b]	Volume/ha[c] (m^3)
1	1480	31.90	16.57	7.84	262.7
2	1150	52.96	24.22	10.76	462.8
3	2260	30.59	13.13	8.44	203.1
4	1410	43.08	19.73	9.70	301.3
5	4420	46.58	11.59	13.68	326.7
6	3560	39.95	11.96	11.55	274.4

[a] Quadratic mean diameter.
[b] Curtis' (1982) relative density.
[c] Total volume per ha.

Table 7. Change in structural conditions of plots (1997 to 2003 inclusive).

Plot #	Changes									
	Stems/ha (period)	Stems/ha (yearly)	BA/ha (period)	BA/ha (Yearly)	Dq[a] (period)	Dq (Yearly)	RD[b] (Period)	RD (Yearly)	Volume/ha[c] (Period)	Volume/ha (Yearly)
1	-30	-4.3	3.70	0.53	1.15	0.164	0.66	0.094	38.6	5.51
2	-30	-4.3	2.59	0.37	0.90	0.129	0.33	0.047	47.5	6.79
Yearly Average		**-4.3**		**0.45**		**0.146**		**0.071**		**6.15**
3	-90	-12.8	-4.03	-0.58	-0.57	-0.081	-0.91	-0.130	-13.7	-1.96
4	-50	-7.1	2.84	0.41	0.99	0.141	0.40	0.057	33.7	4.81
Yearly Average		**-10.0**		**-0.09**		**0.030**		**-0.036**		**1.43**
5	-600	-85.7	1.53	0.22	0.90	0.129	-0.10	-0.014	24.2	3.46
6	-440	-62.9	2.43	0.35	1.03	0.147	0.20	0.029	28.0	4.00
Yearly Average		**-74.3**		**0.28**		**0.138**		**0.007**		**3.73**

[a] Quadratic mean diameter.
[b] Curtis' (1982) relative density.
[c] Total volume per ha.

Summary of Plot Growth Over the Three Measurement Periods

Periodic yearly growth rates, for each of the plots in each of the three growth periods, are shown in Figures 1 and 2 for basal area per ha and volume per ha, respectively. There was considerable variation among plots within periods, and within the same plots among periods. There were no apparent trends by plot or stand structure when the data are viewed on a unit area basis. For example three different plots had the highest basal area growth for each of the three growth periods (1988-1992: Plot 6; 1993-1996: Plot 3; and 1997-2003: Plot 1). The variability is due, in part, to the impact of mortality of larger trees on unit area growth. The impact of mortality is most apparent as reflected in the negative growth rate for Plot 3 in the 1997-2003 growth period; however, it is apparent that other factors are at play as well.
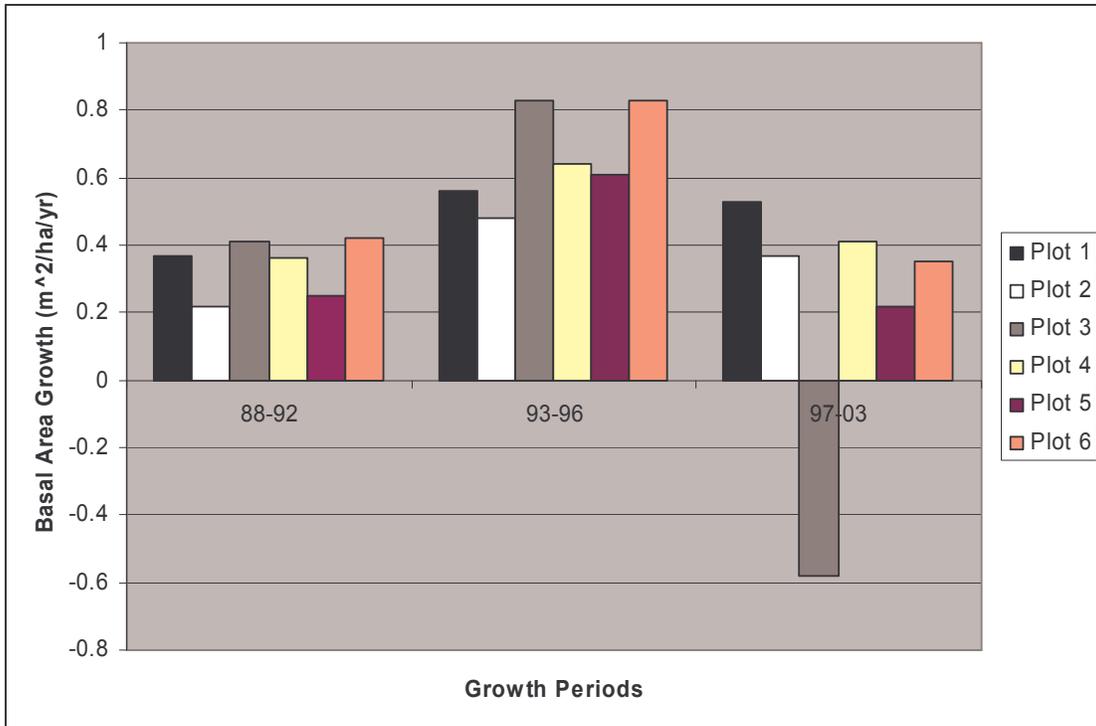
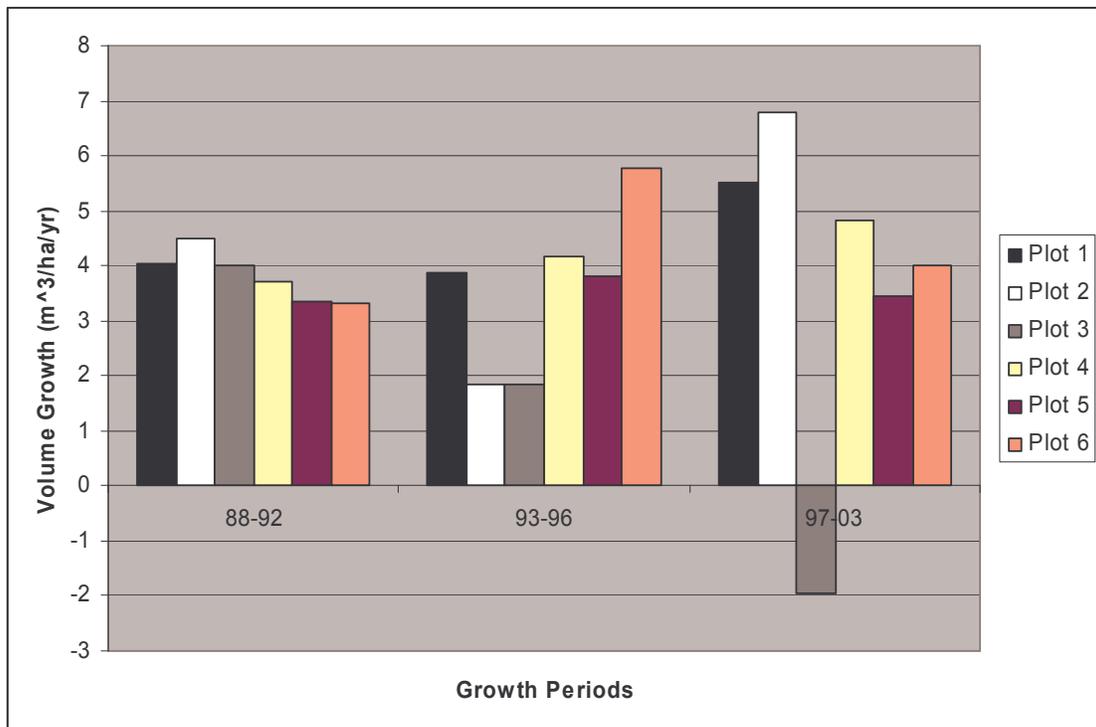Figure 1. Basal area per ha growth by plot and period.

Figure 2. Total volume per ha growth by plot and period.

Annual gross volume growth on five of the six plots over the entire period (total histogram heights in Figure 3) was relatively constant; the gross volume growth on Plot 3 was about 0.5 to 1.0 m^3/ha/year lower than that of the other plots for some reason. Average net annual volume growth was more variable, and was considerably lower on Plot 3 than on the other plots due to the death of a few large trees, as mentioned previously.

Management Implications

Based on the growth of these six plots, established across a range of stand conditions, it appears that unit area growth in both basal area and volume is both highly variable and apparently insensitive to stand structure. If this holds over a wider area, it means that interior Douglas-fir stands can be maintained in a variety of stand structures, to meet a number of different objectives, without unduly sacrificing basal area and volume growth. The limits to where residual structures and densities begin to affect growth in unit area basal area and volume are not apparent from the relatively wide range of stand structures examined in this study.
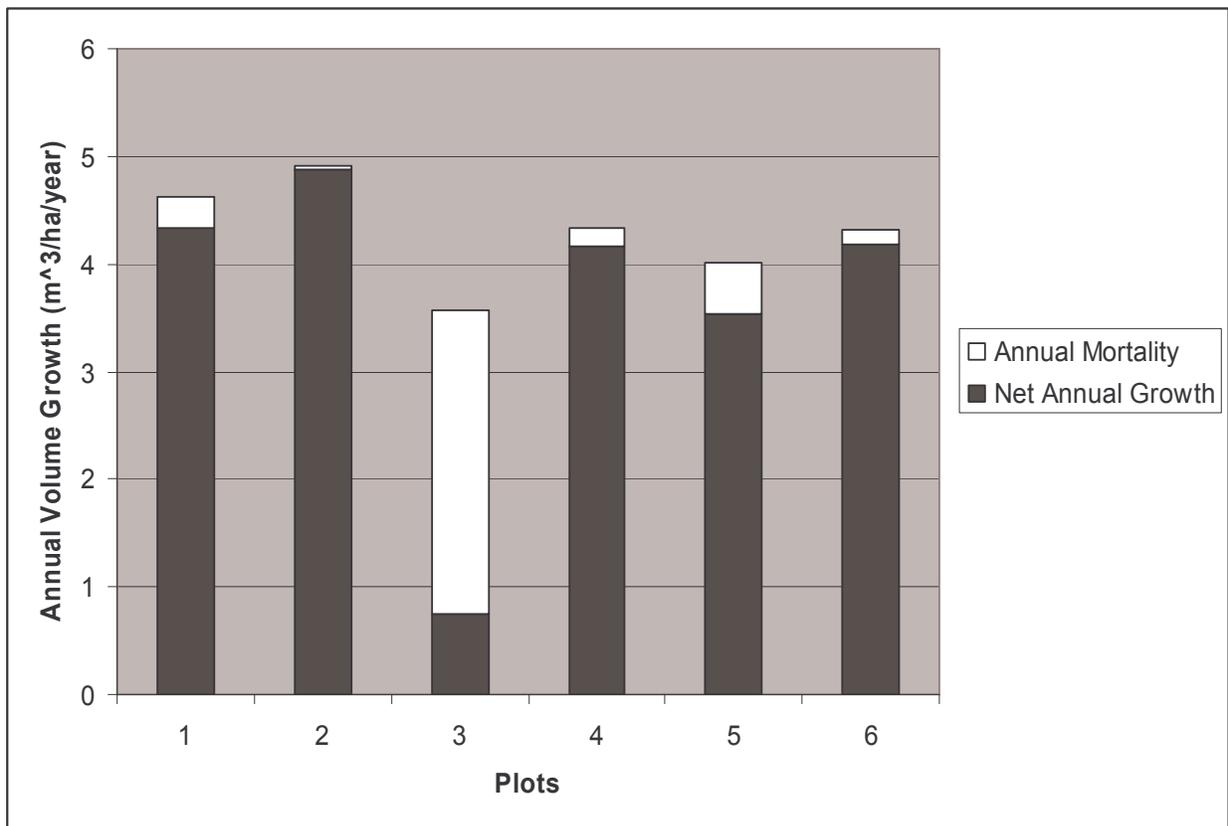

Figure 3. Net annual total volume growth, annual mortality, and gross annual total volume growth (total histogram height) for the six plots since plot establishment.

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